AIR FORCES MANUAL NO. 64 · RESTRICTED

FIGHTER GUNNERY

ROCKET FIRING

DIVE BOMBING

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Fighter Gunnery Rocket Firing Dive Bombing

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1 May 1945


U.S.

FOREWORD

This is a manual for fighter pilots. Its purpose is to teach you how to hit aerial and ground targets with machine gun fire, rockets and bombs. The Army Air Forces' foremost research and training experts have worked together to make this a complete and up-to-date summary of what we know about the employment of these weapons. As you will see, we know a great deal.

If properly used, these weapons give you—an individual—the greatest destructive force in the hands of any single fighting man on land, sea or in the air. And there is no reason why you, with your already demonstrated abilities, should not be able to learn in a relatively short time, everything between these covers.

There is no detailed discussion of tactics in this manual. But the gunnery methods here described naturally apply to combat as well as to immediate training problems. You will do well to absorb these methods completely, to make them, in fact, part of your second nature.

H H Arnold

Commanding General, Army Air Forces

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Air Forces Manual No. 64, *"Fighter Gunnery, Rocket Firing, Dive Bombing,"* is published for the information and guidance of all concerned.

BY COMMAND OF GENERAL ARNOLD:

HEADQUARTERS ARMY AIR FORCES
OFFICIAL
WASHINGTON, D.C.

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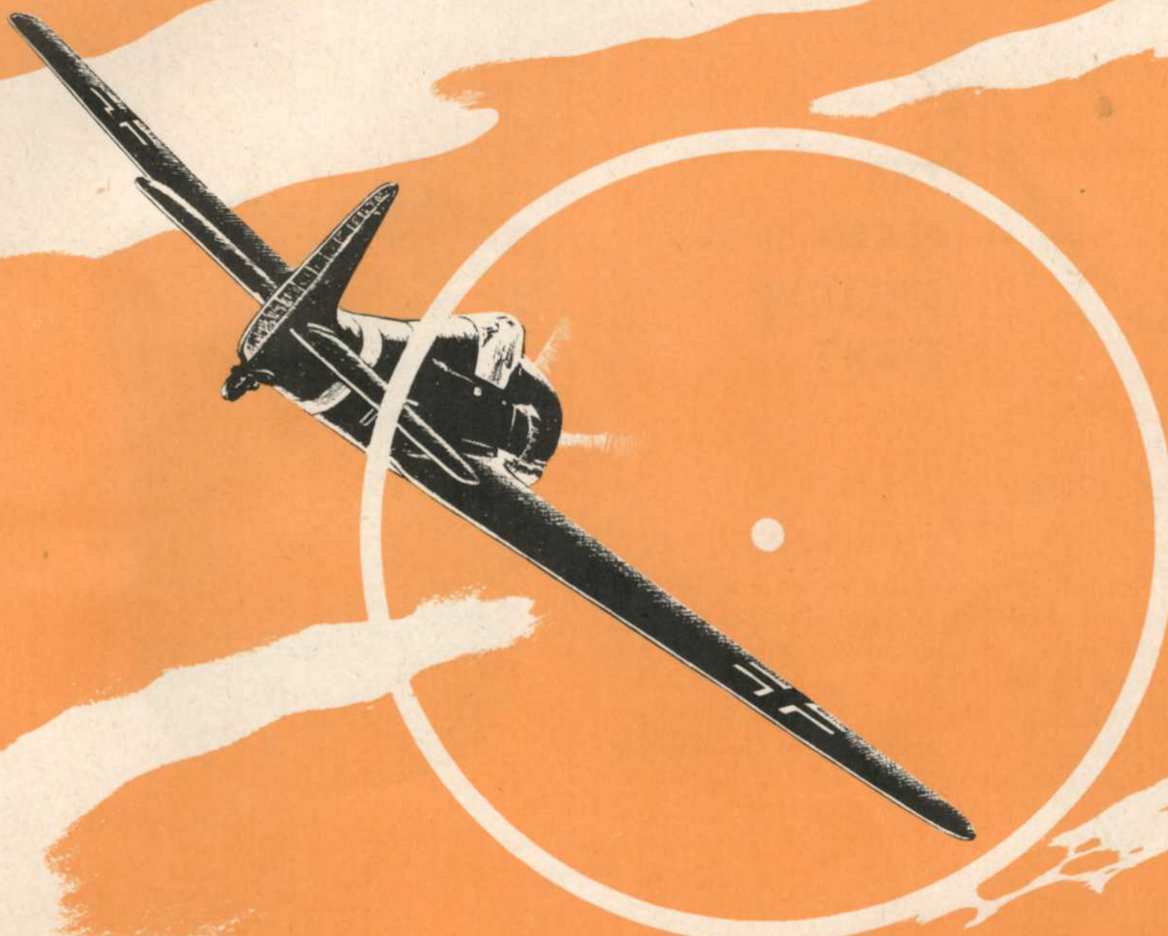
SECTION I

Aerial Gunnery



This section on air-to-air firing is a refresher course. It assumes you know the fundamental concepts of aerial gunnery as given in "Fighter Gunnery", published for the Training Command. It also assumes you are a well-qualified pilot of your particular fighter airplane. Although this section includes all necessary information, it has a minimum amount of theoretical and technical data.

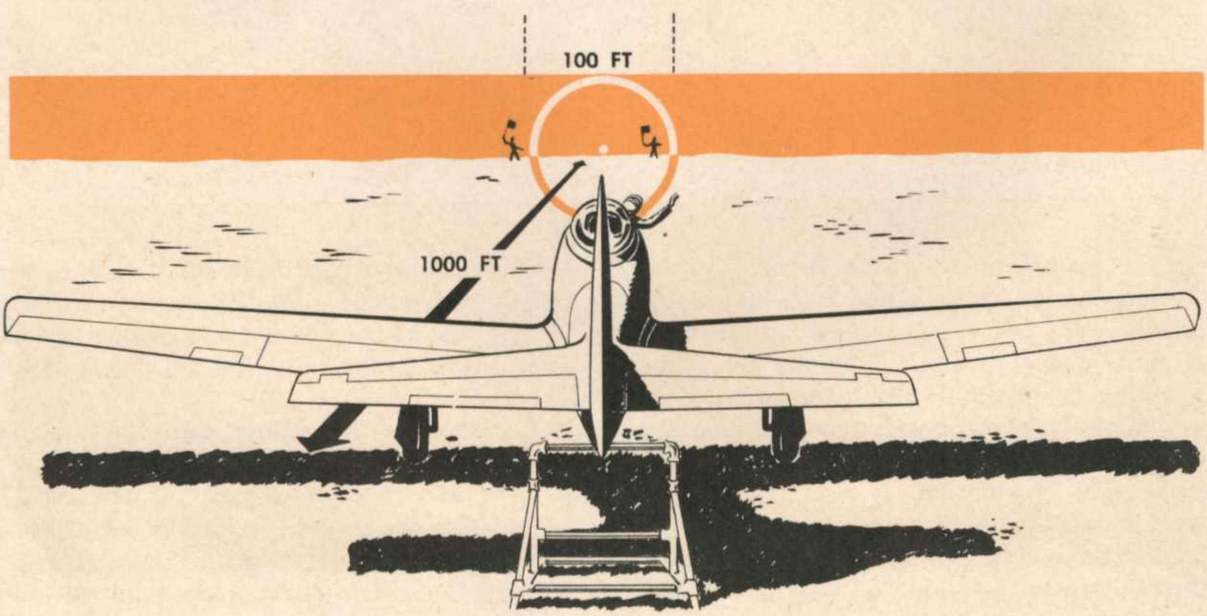
The theme of this section is sight pictures—the relation of the sight to the target. If you know which sight pictures result in hits, if you can fly well enough to get these pictures, and if the guns are harmonized so the bullets properly intersect the sight line, you will be an expert.

Deciding on the proper sight pictures is relatively simple. Do this on the ground. Then, armed with this knowledge, "fly the sight" and plaster the target. Flying the sight properly requires intensive and analytical practice because the bullets, the airplane, and yourself

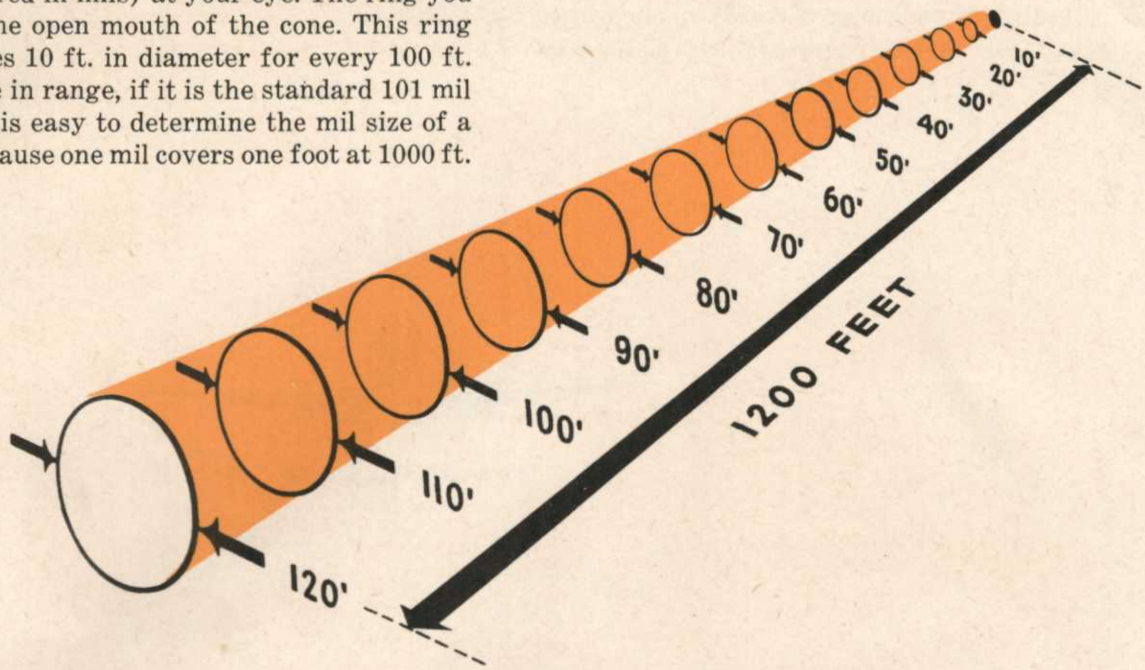
have certain limitations that restrict shooting. Use the information in this section to brush up on these limitations and plan a good, effective attack based on sight pictures that result in hits.

THE FIXED OPTICAL SIGHT

The optical sight measures range and deflection. Other sections of this manual explain its use in rocket firing and dive bombing. To use the sight in air-to-air or air-to-ground attacks, you must know the size of the ring. There are various sizes in common use, so measure the ring in your own fighter.

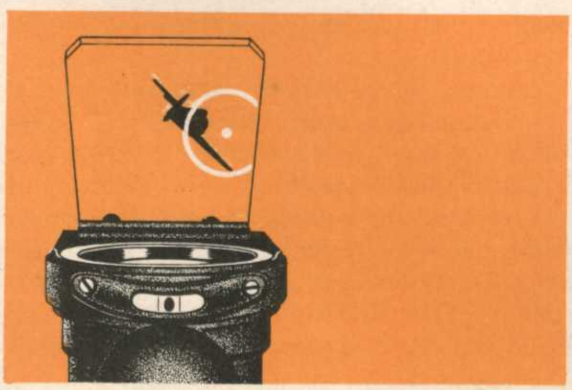


The ring is a cone of light. It forms an angle (measured in mils) at your eye. The ring you see is the open mouth of the cone. This ring increases 10 ft. in diameter for every 100 ft. increase in range, if it is the standard 101 mil ring. It is easy to determine the mil size of a ring because one mil covers one foot at 1000 ft. range.

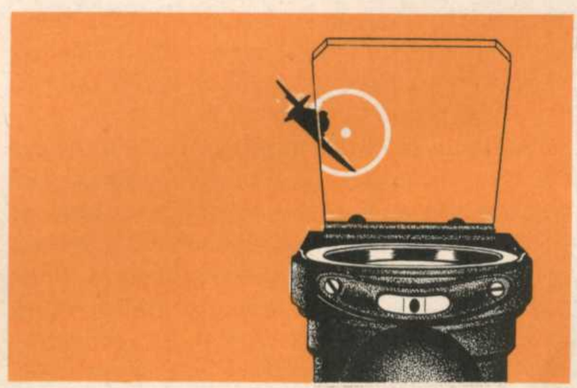


HEAD MOVEMENT DOES NOT DISTURB ALIGNMENT OF SIGHT AND TARGET— BOTH MOVE TOGETHER

HEAD IN CENTER



HEAD TO THE RIGHT



HEAD TO THE LEFT

Since you see the ring at the same range as the target (where your eyes are focused), you can estimate the range if you know the target size. It fills one-third, one-half, etc. of the ring at various ranges. Choosing a good range picture is one of the first steps in preparing sight pictures.

RANGE

Before you can establish a sight picture that results in hits, you must know the **limits** of effective range and the **best** range at which to fire. A fighter's machine guns have limitations, as do all weapons—they have a maximum limit of effective range and a most effective range. Since it is difficult to time and execute high speed attacks on close range targets, many pilots have an unconscious tendency to fire when too far away. The following paragraphs point out why it is futile to open fire out of range.

The farthest range at which the bullets are effective is neither the maximum range the gun can shoot nor the maximum range at which the bullets still have penetrating power. A fighter's bullets become ineffective when they still have a high velocity and striking power, because you can aim them accurately and control their trajectory only over short ranges. Aiming is an **angular** problem. While a small sighting error makes little difference at close range, the error magnifies as the range increases.

A 1000 ft. range, it is difficult for an expert to hold his sight within five or six feet of the desired aiming point; at 1500 ft., to hold it within eight or nine feet. You can prove this by making a pass and trying to hold the pipper exactly on the target. Enemy airplanes present a six to eight feet target area, so your own ability to aim becomes a major limit to effective range.

Various forces beyond your control act on the bullets and limit their effective range. THE CONE OF BULLET DISPERSION from a Cal. .50 fighter machine gun is about 4 mils for 75% of the rounds. Even with multiple guns, the lethal bullet density is unsatisfactory for air firing at ranges exceeding about 1000 ft. THE EFFECT OF GRAVITY on the bullets is relatively small over ranges requiring less than one-half second of flight. Beyond these ranges, bullet drop increases rapidly.

Proper gun harmonization can compensate for gravity drop for the first 1200 ft. of flight. CHANGES IN BULLET VELOCITY caused by changing airplane speed and variable air resistance limit the accurate firing range. This is important because fast moving targets require lead allowances that depend on carefully calculated bullet speed data. Since it is impossible to figure the precise target range, air density, and lead required each moment, you must use an **average bullet velocity.** This gets results only at short ranges, because the farther the bullet travels, the greater the error caused by target movement.

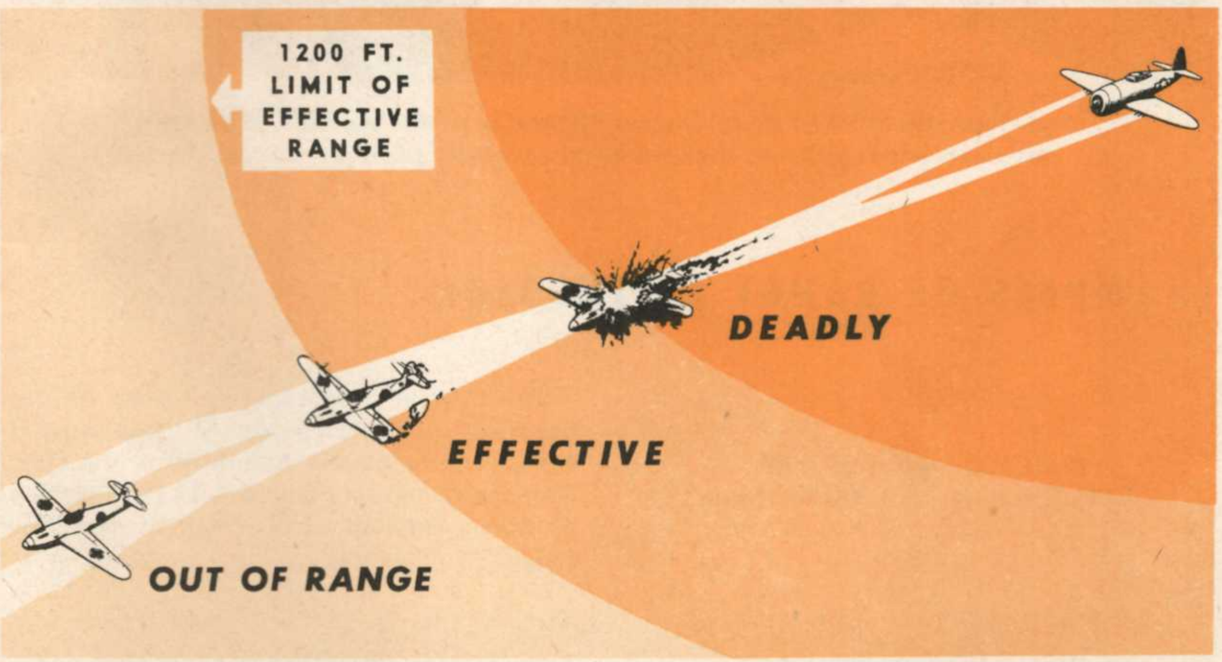
To determine the range limit of reasonable lead accuracy, using an average bullet velocity, consult ballistic tables to find: the maximum range at which changes in altitude and airspeed make no appreciable change in the bullet's speed, and the maximum range within which the bullet's time of flight is practically proportional to the range covered.

Such a study of Cal. .50 AP ammunition reveals that:

AT 600 FT. RANGE, excellent accuracy is possible because variations in the bullet's time of flight are slight under all operating conditions of speed and altitude.

AT 1200 FT. RANGE, the bullet's speed is still consistent enough to result in reasonable accuracy.

BEYOND 1200 FT. RANGE, changes in time of flight under different operational conditions are too great to permit accuracy of lead.



You have undoubtedly concluded by now that the **limit** of effective range is about 1200 ft. and that the **most** effective range is closer and depends on your particular airplane's harmonization. Since the rate of closure on a target is usually high, you cannot shoot only at the most effective range. You are not there long enough to get in a good burst, so try to bracket this best range. Range estimation becomes a simple problem because you only have to recognize sight pictures that are IN range or OUT of range—1200 ft. or less, 1200 ft. or more.

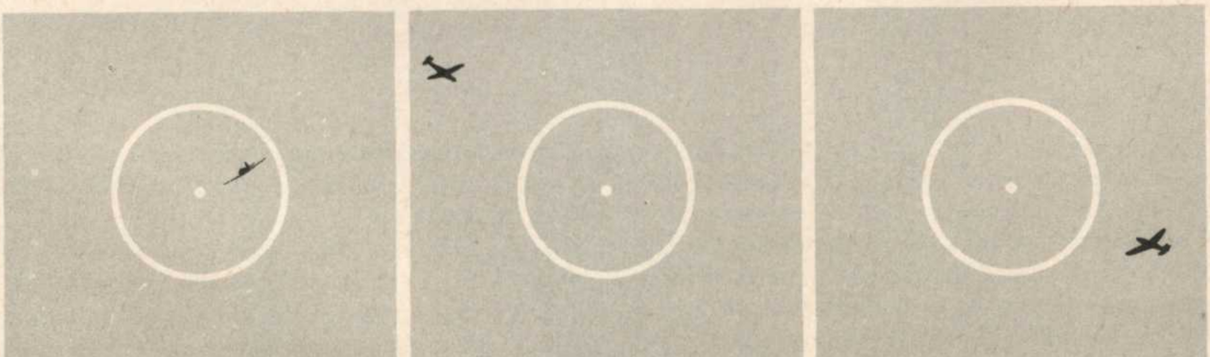
Since most combat deflection shots are at less than 40° angle off, use the wingspan for target size and forget about target length. Just remember, at higher angles off, the foreshortened wingspan does not fill quite so much of the ring as it does at the dead astern position.

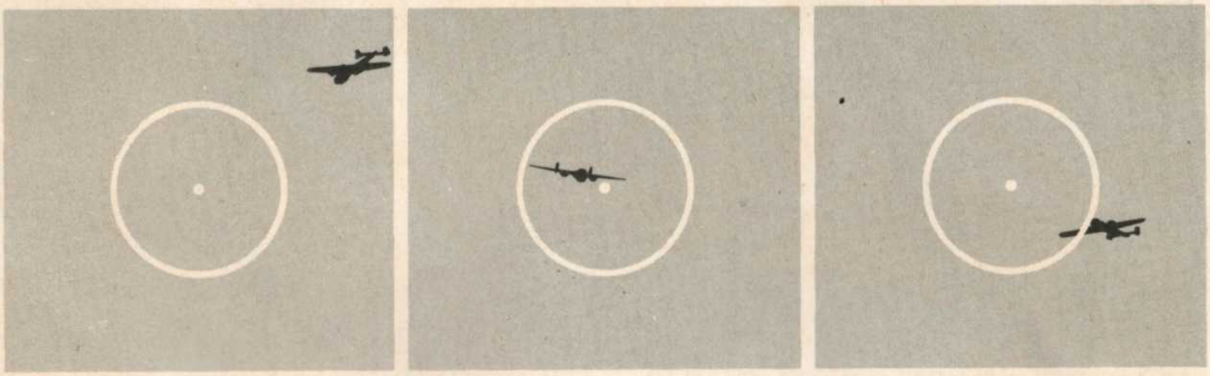
In combat you have to solve these problems in a few seconds. It's a rare occasion when you can make a long, carefully planned approach.

EXAMPLES OF RANGE ESTIMATION

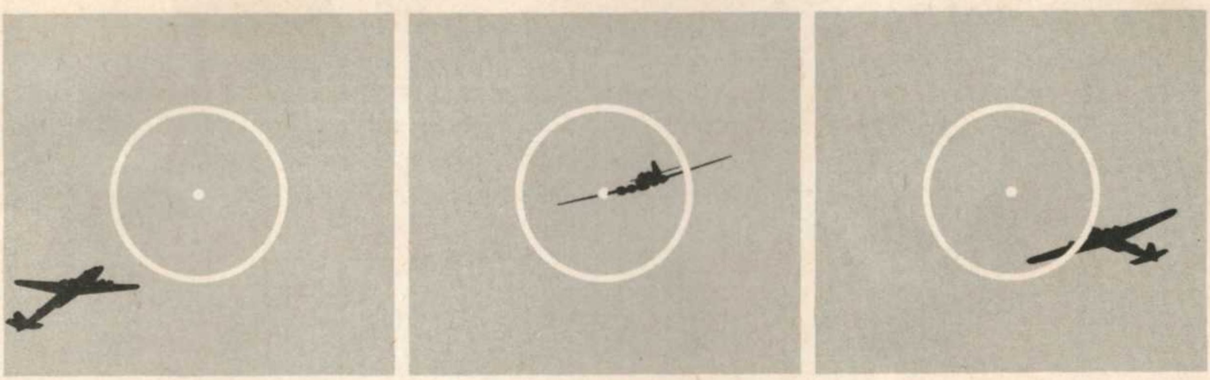
With 100 mph ringsight
120 ft. diameter at 1200 ft. range

The average single engine enemy fighter has about a 35 ft. wingspan. At firing range it equals approximately **one-third** of the ring. Two-engine fighters having a 50 ft. wingspan fill about **one-half** of the ring at open fire range.





Enemy medium bombers average 75 ft. and fill about **two-thirds** of the ring when they are in range.



The average heavy bomber has a 110 ft. wingspan and is in range when it almost fills the **entire** ring.

In any single combat theatre, only a limited number of enemy airplane types appear as targets. It follows then, that you must:

1. Know your ring diameter at 1200 ft.
2. Compare it to the target's span by actual drawings of the sight picture at that range.

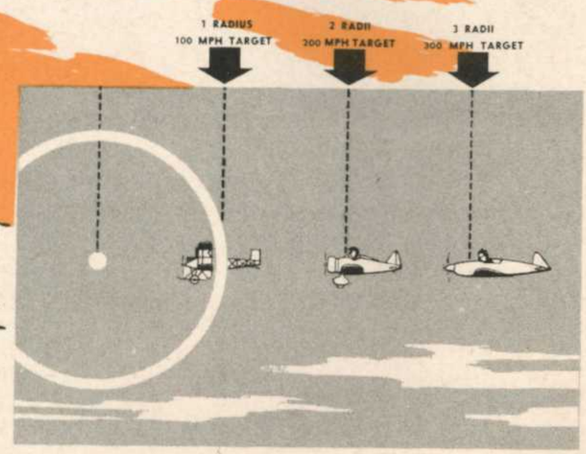
Aces of this war know they have no time for intricate calculations. Memorize sight pictures for expected targets before take-off. And remember, these sight pictures are for maximum range. You can get better hits at shorter ranges.

The standard 6 ft. by 30 ft. towed target

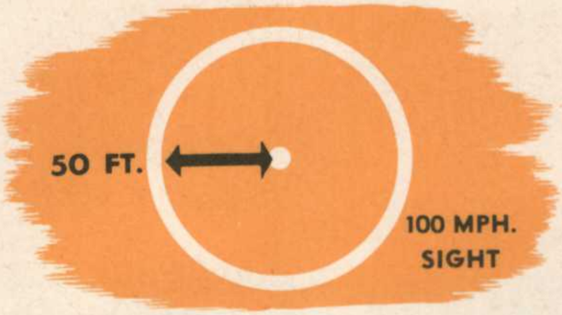
equals one-half of one radius at 90° angle off, 1200 ft. Since it foreshortens as the angle off decreases, it fills about one-third of one radius of 45° angle off and one-fourth at 30°. All of these sight pictures are computed at the 1200 ft. maximum range limit.

DEFLECTION ALLOWANCE

Another step in setting up sight pictures is deciding on the amount of deflection to allow the target. If the target is moving directly toward or away from you, there is no deflection problem. Aim straight at him, fly smoothly, and let him have it when he gets in range!



However, most aerial shooting requires deflection allowance unless you attack with complete surprise and allow no opportunity for evasive action. Whether the necessary deflection is large or small, you must allow the exact amount. Most stern shots are not dead astern and point blank aim results only in near



misses. The following information will help you estimate deflection allowance.

SPEED VALUE OF THE SIGHT

Fighter pilots call the 101 mil sight a 100 mph sight because one radius is the proper deflection allowance for a 100 mph target at 90° angle off. This lead value of one radius is based on a bullet velocity of approximately 2900 ft. per second or 2000 mph (Cal. .50 M2).

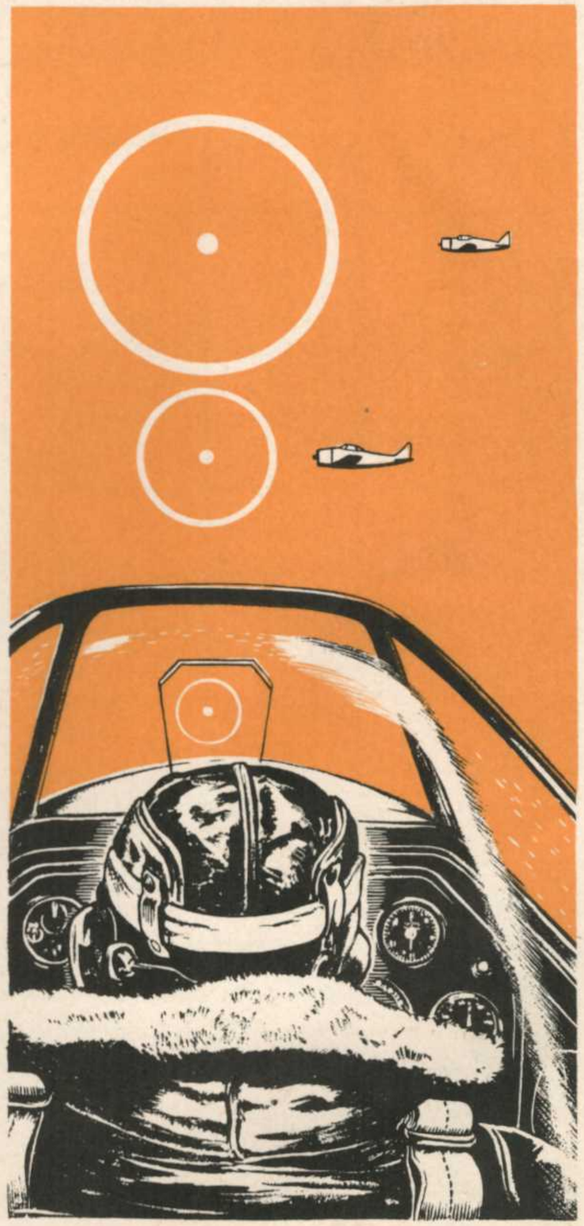
To determine the lead value of a sight, remember that the lead value compares to the average bullet velocity, just as the length of sight radius compares to the range. Since the 101 mil sight radius is always 5% of the range (i.e., 50 ft. at 1000 ft.), the lead value is always 5% of the average bullet velocity.

The size of the ring increases with range, thereby compensating for increased lead. The radii lead for any one angle off is the same regardless of range—if you are close enough for the bullet velocity to remain fairly constant.

You must be thoroughly familiar with the operational speeds of enemy airplanes in your area. The determination of target speed is only an estimate, but shrewd judgment and careful analysis of intelligence reports can result in an accurate estimate. Learn the cruising and maximum speeds of airplanes you are likely to encounter.

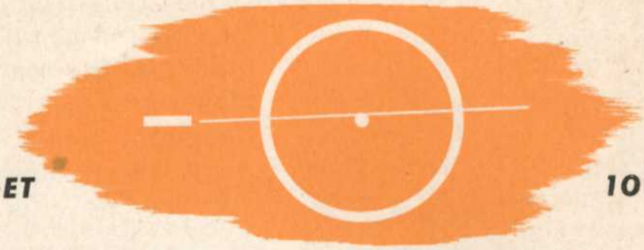
1. If the target is flying level, approximately along its longitudinal axis, allow lead for cruising speed.
2. If he is flying tail-high in level flight, he is at maximum speed.
3. When the target is climbing, allow lead for three quarters of its cruising speed.
4. If he is diving, he can be doing anything up to terminal velocity.

Up to now, this discussion has dealt only with 90° deflection. The necessary deflection decreases as the angle off decreases, becoming zero at dead astern. The percentage of the 90° lead necessary for the other angles off is the

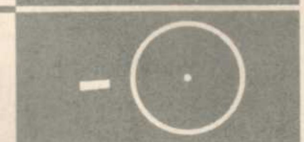
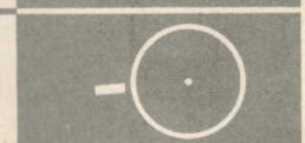
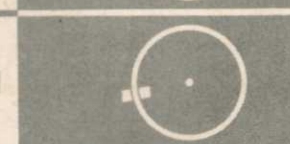


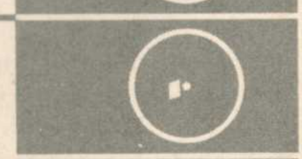
same as the sine of the angles. Multiply the 90° lead by the sine of each major angle off to get the proper deflection for those angles.

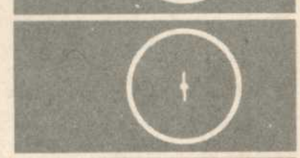
Notice in the following table how the lead changes gradually at high angles off and de-



200 MPH TARGET **100 MPH SIGHT**

ANGLE OFF	SINE	90° RADIUS LEAD	RADIUS LEAD	SIGHT PICTURE
At 90°	1.	times 2 gives	2 radii lead	
At 75°	.96	times 2 gives	1.9 radii lead	
At 60°	.87	times 2 gives	1.7 radii lead	
At 45°	.71	times 2 gives	1.4 radii lead	
At 30°	.50	times 2 gives	1. radius lead	
At 15°	.26	times 2 gives	.5 radius lead	





Before you go up to fire at the 200 mph target, you can create a mental sight picture of how you will vary your lead as you turn with it. This sight picture should include your range estimation—that is, the comparative size of the ring and target.

creases much more rapidly at the lower angles. This being true, you must make extra careful deflection allowances at less than 35° angles off.

It is not easy to recognize various angles off. It requires practice, drill, and more practice. This recognition is an integral part of all sight pictures.

ALIGNMENT

The comparatively narrow width of aerial targets makes alignment a most important problem. You can realize how important by remembering that at normal firing ranges, target widths are usually about 6 mils. It takes an excellent pilot to hold the pipper within this area. Obtaining a high standard of proficiency requires much practice in flying the sight. Practice coordinated turns of various rates, flying the sight exactly along the horizon until you have precise control of it.

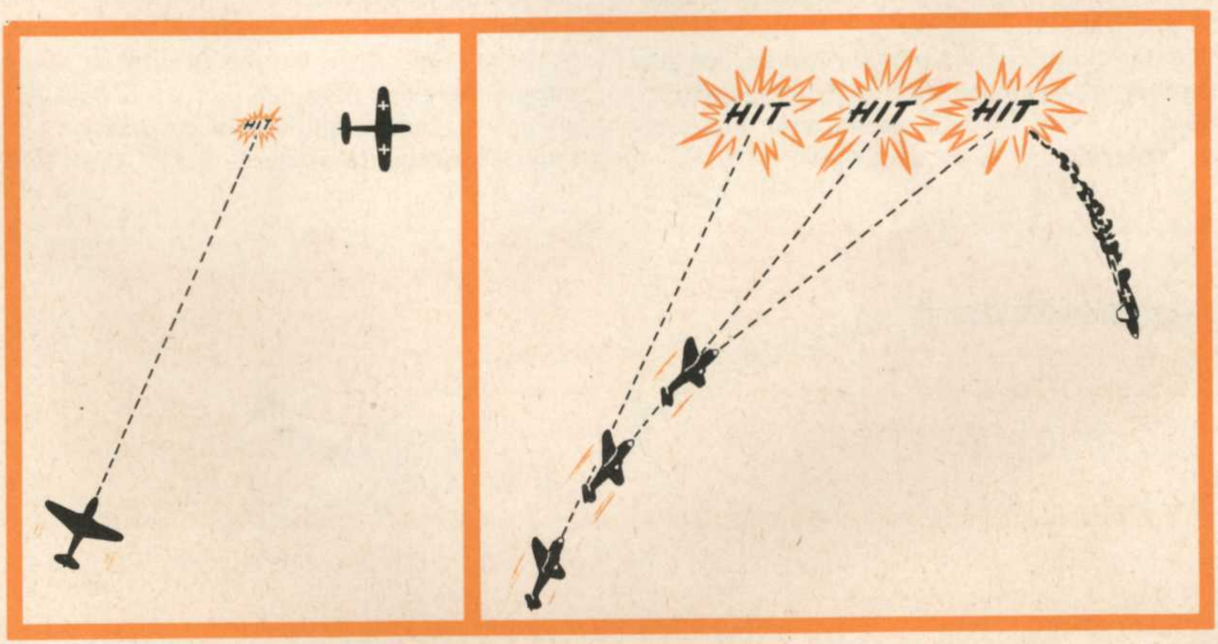
Sometimes a target is not going in the direction of its longitudinal axis. You must train your eyes to recognize the **true line of** flight. Accurate estimates of target speed give clues to flight direction. You know airplanes fly nose-down at high speeds and nose-high at slow speeds.

Some fighter pilots believe observation of target movement against the background helps line estimation. Do this by focusing on the sight with the target off the center of vision. Be line-of-flight conscious and practice estimating it at every opportunity in the air and on the ground.

FLYING THE SIGHT

You are acquainted with the problems of sighting. You know your best range, the limits of effective range, and how to measure these ranges. You know how to compute deflection allowances for the various angles off. Now review the application of these sighting fundamentals.

When attacking a moving target from any position other than head-on or dead astern, you must turn with the target if you expect to hit it more than once. The result: you fly a curved path toward the target. This is a CURVE OF PURSUIT. The required deflection allowance and range decrease as the angle off decreases.



Instead of laying down a path of fire and maybe getting one hit per gun if he flies through the burst —

Turn with the target, holding the proper lead as you turn so you hit him again and again in the same pass.

There are definite limitations to flying a curve. You cannot swing the airplane in any direction as easily as you do a skeet gun. It won't turn fast enough. Three factors determine the rate of turn for any one attack:

TARGET SPEED: The faster the target, the faster the turn.

RANGE: The shorter the range, the tighter the turn.

ANGLE OFF: The larger the angle off, the tighter you must rack around to get the proper sight pictures.

The combination of these three factors sets up the rate of turn requirements for any attack. The difficulty is that many combinations require rates of turn impossible in fighter airplanes because they result in excessive G's.

There is a solution to this problem of turning an airplane at high speeds against a high speed target: PLAN AN ATTACK SO THE RANGE AND ANGLE OFF DO NOT RESULT IN A TURN WITH EXCESSIVE G's.

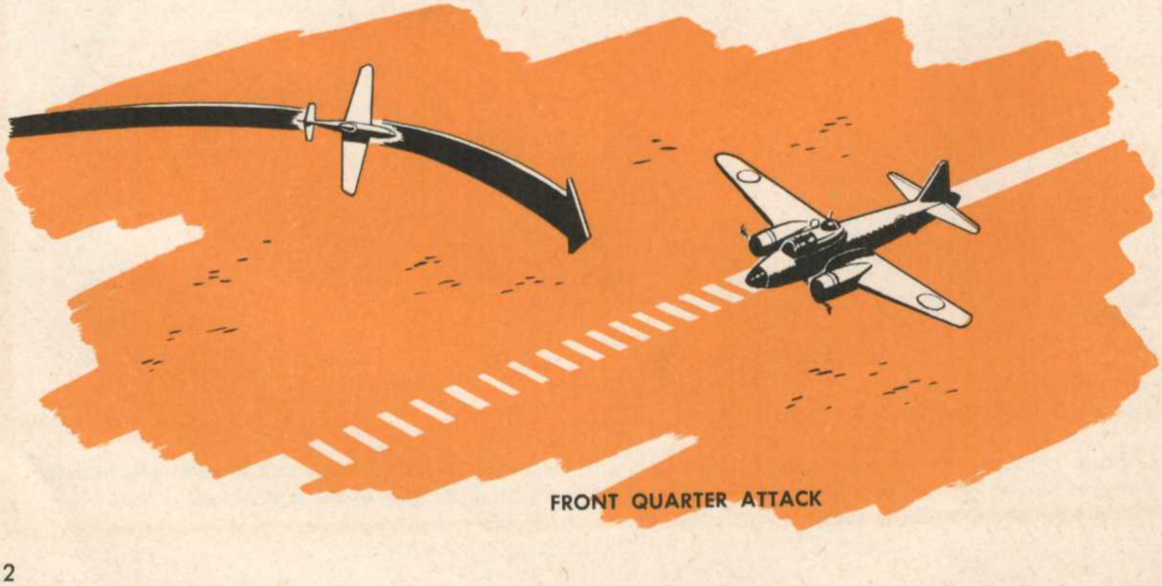
PLANNING AN ATTACK

Before planning an attack, have a general understanding of the various types of attacks and learn what to expect under any given set of conditions.

Attacks are divided into several groups according to the angles off from which you fire: head on, front quarter, beam, rear quarter, and astern.

Head on attacks are very brief because of the high rate of closure.

During a front quarter attack, you can expect the angle off to increase as the curve of pursuit develops. The combination of fast decrease in range and increase in angle off requires a rapid increase in rate of turn. The



FRONT QUARTER ATTACK

expert timing involved makes this attack extremely difficult.

The most common attacks are the beam and rear quarter. In slow training airplanes, the rear quarter attack develops simply as the later part of a beam attack. But the situation is different when you are flying a high-speed fighter against fast targets. If you commit yourself to a beam attack at a range of 1200 ft. or less, the amount of turn required to follow the target builds up rapidly as you close in and necessitates breaking off the attack after only one or two seconds of fire. If, under the same speed conditions, you plan the attack to arrive in range at a smaller angle off, the necessary turn is not so tight and the firing time is longer. When operating speeds increase, as is the case at higher altitudes, there is only one alternative—to fire at smaller and smaller angles off. EVEN EXPERTS FIND IT DIFFICULT TO AIM ACCURATELY IN A TURN OF MORE THAN THREE OR THREE AND ONE-HALF G's.

Here are some possible attacking speeds and target speeds. A study of these combinations will help you plan an attack resulting in an angle off within effective range that permits you to fire a three-quarters to seven second burst. This table indicates why combat films usually show enemy aircraft being destroyed from small angles off.

POSSIBLE CURVES OF PURSUIT

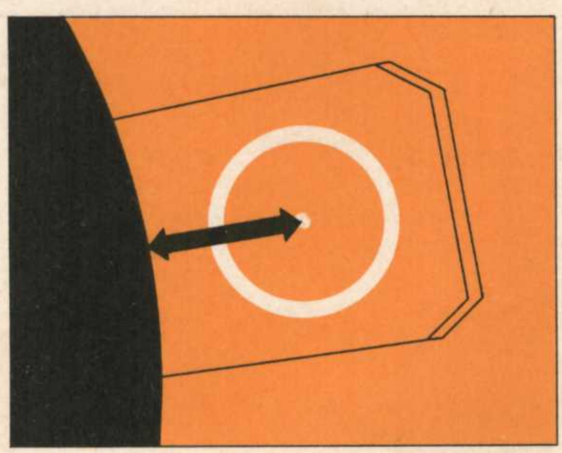
FIGHTER TRUE SPEED	TARGET TRUE SPEED	ATTACK POSSIBILITIES
150 mph	130 mph	A two to four second burst is possible from *any* angle off if the open fire range is 750 ft. or more. The rate of turn increases up to 55° angle off, and then decreases.
250 mph	150 mph	If you are at 70° angle off at 1200 ft., the turn requires less than three G's and you can fire down to dead astern—six to seven seconds. The maximum bank occurs at 30° angle off. Beam attacks are possible if you open fire at 1200 ft. Two and one-half to three and one-half G's and time for a one to two second burst results.
250 mph	200 mph	Attacking from 65° angle off at 1200 ft. results in two or three G's and you can fire to dead astern six to seven seconds. The maximum bank is at about 50° angle off. Opening fire on a beam attack at the 1200 ft. limit of effective range allows a one to one and one-half second burst with three or four G's.

CONTINUED NEXT PAGE

300 mph	200 mph	Attacks beginning at 1200 ft. range, 50° angle off, require less than three G's. You can fire for five seconds to dead astern. Maximum bank is at about 45° angle off. Beam attacks requiring less than three and one-half to four G's are impossible.
350 mph	300 mph	Attacks above 45° angle off are impossible at less than four G's. If you open fire at 1200 ft., 35° angle off, you can fire for six or seven seconds to dead astern and never draw more than three and one-half G's. Maximum bank occurs at 50° angle off, before you start firing.
400 mph	350 mph	Attacks requiring less than four G's are impossible within 1200 ft. above 30° angle off. You can fire for more than three seconds by opening fire 20°, and continuing to dead astern.
450 mph	400 mph	Attacks impossible at angles off greater than 20°.

The firing times listed in this table include only the time on curves of pursuit. Fire as long as necessary after reaching the dead astern position. But — the enemy isn't going to let you get that far if he can help it, so get him on the curve!

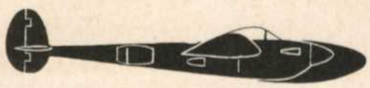
Pilots of most fighters must consider another limitation when planning an attack. The enemy probably has his throttle bent forward and is going like a scalded duck. This requires a large amount of lead at high angles off, and your airplane has certain limitations in the amount of lead possible. As your effort to stay with the target has put you in almost a vertical bank, you may not be able to see him over the airplane's nose and still allow the necessary deflection. In a P-4D, for example, less than two radii lead over the nose is possible when the airplane is in more than a 45° bank.

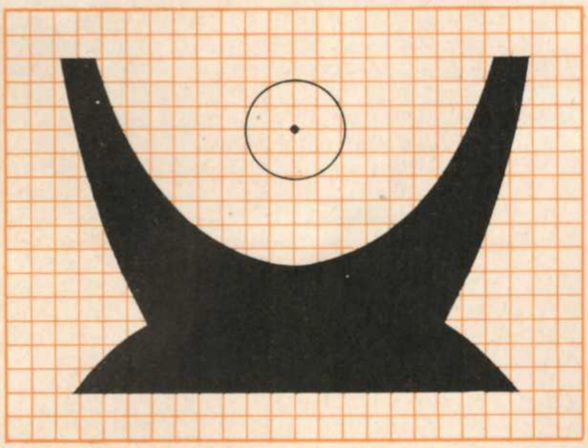


VISIBILITY LIMITATIONS OVER THE NOSE OF VARIOUS FIGHTER AIRPLANES

(Check your own airplane)

P-38





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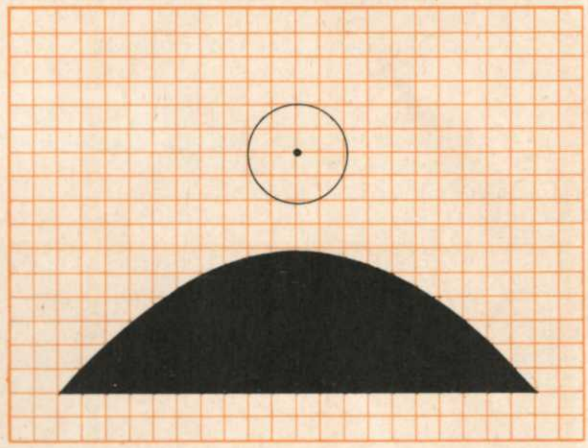

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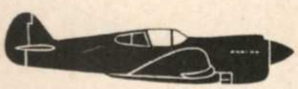

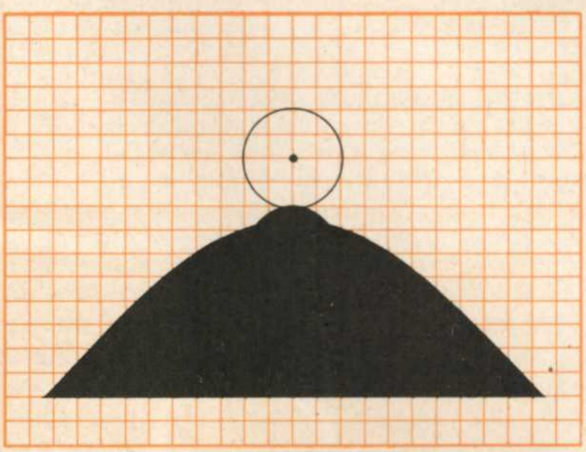

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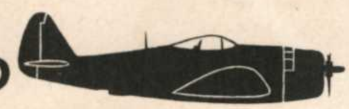
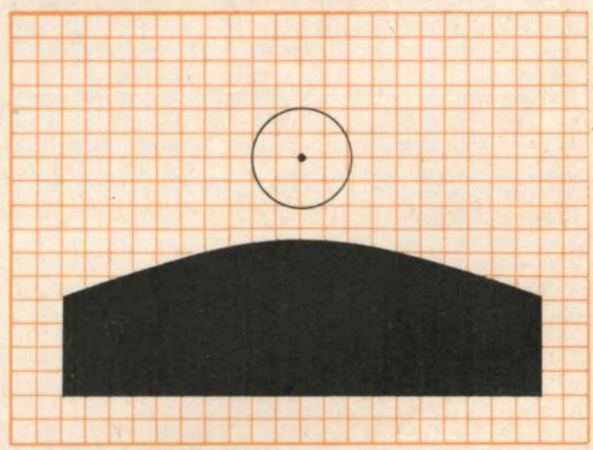




SCALE 1 SQUARE = 25 MIL

A study of the table on curve of pursuit possibilities indicates a visibility of two and one-half to three radii is ample for any attack possible within effective range.

("There are many possible curves of pursuit, all of which are within the 1200 ft. maximum range limit. On some of them you fire from large angles off. On others you fire from smaller angles off as you arrive in range. These attacks may be from above or below, one side or the other, front or rear. But in all cases, plan the attack so the rate of turn required does not exceed your limitations.")

You will be successful in gunnery practice and in combat only if you apply the fundamental sighting theories. Plan curves of pursuit that do not exceed the limitations of yourself, the airplane, or the bullets.

MUSH

Unfortunately, the fundamentals do not tell the whole story because they are based on the assumption that the sight line actually indicates the bullets' path. This is not always true.

The bullets' path depends on the direction the gun bore is pointing; but when the airplane is not flying in the direction of the gun bore, the bullets travel in a new direction. For example: the guns are harmonized for a definite attitude or indicated airspeed. Ballistic errors result if you do not fly at this speed because your flight path is not in the direction the guns and sight are pointing. Actually, these errors are small unless you fly extremely below harmonization speed.

Other errors, caused by the aerodynamics of the airplane or how you fly it, are more

serious. Slips, skids, and rough flying throw the bullets off the line of sight. This is a serious error, so FLY SMOOTHLY AND KEEP THAT BALL CENTERED!

If you fire while turning, as is always the case on a curve of pursuit, acceleration forces (G's) are induced on the airplane, resulting in what most pilots call mush. To support these G's with additional lift, you increase the angle of attack by applying back pressure on the stick. The sight line is inside the actual flight path and the bullets deflect away from the sight line perpendicular to the plane of bank.

It is difficult to make rigid conclusions on the effects of G's and the necessary sighting compensations because they vary with the type, speed, altitude and attitude of the airplane. However, an analysis of a few sample conditions gives an idea of the size of the error and necessary sighting corrections.

APPROXIMATE MIL ERROR CAUSED BY G's

aircraft harmonized at 250 mph IAS

ALTITUDE	IAS	FIGHTER	2 G's mil errors	3 G's mil errors	4 G's mil errors
SEA LEVEL	250	P-47	7	14	21
		P-51	6	12	18
		P-38	6	12	18
SEA LEVEL	200	P-47	13	22	31
		P-51	11	18	26
		P-38	13	22	31
20,000	250	P-47	9	18	27
		P-51	7	14	21
		P-38	7	14	21
30,000	250	P-47	11	22	33
		P-51	9	18	27
		P-38	9	18	27

In an overhead attack, the error caused by G's is a lead error.

In a side attack, the error is perpendicular to the plane of bank. If you allow lead in the direction of apparent motion (using the background movement for alignment) the error is one of lead only. Reason: the vertical component of mush in your airplane causes the target to appear to rise.

A GOOD RULE

Fairly tight turns at low altitude require one-third radius additional lead. At high altitudes, allow one-half radius extra lead for G's.

IF YOU ARE A BEGINNER

Before starting gunnery practice, there are a few things you should be aware of and look for in yourself. You are going to have to teach yourself how to shoot. There will be no one in your fighter to help. You must know what to learn and how to learn it.

You have combined flying knowledge with practice, in order to develop your flying ability. Now, combine this flying ability with gunnery knowledge and practice. Before each mission, carefully plan what you are going to practice. When in the air, conscientiously practice what was planned. **Don't become discouraged and try one thing, then another.** Poor results mean you are not doing what you planned. Continuous practice on one plan produces results. Learn what to do when in firing position, and don't worry about all the different ways to get into this position. After you develop good firing technique on one type pass, you can practice different approaches.

WARNING: Don't become mechanical. Keep thinking and analyze each attack.

The success of an attack on an aerial target depends on the positioning for the attack, timing of turns, smooth flying, and accurate sighting. Here is an example of how to plan an attack on a towed target.

The target has a true airspeed of 200 mph at 5000 ft. The fighter is a P-47D harmonized at 260 mph I.A.S., equipped with a 101 mil sight. This sight installation allows a two radii lead over the nose.

The first thing to decide on is a firing position that will not exceed the airplane's limitations. The angle off must permit the allowance of enough radii lead over the nose. Tight turns result in heavy G's, requiring large changes in the angle of attack. If possible, avoid excessive acceleration forces. After selecting an open fire position, analyze the attack to see if you made a good decision.

You decide to fire from 45° to 30°. Deflection allowance for this target speed at 45° is 65 mils. The Curve of Pursuit table, pg. 13, indicates two and one-half G's will result. Add 10 mils for the G error and the lead is 75 mils or one and one-half radii for the open-fire deflection. Your P-47 has two radii lead over the nose, and two and one-half G's are not excessive. You have made a good choice.

Next, plan how to get to this firing position. The advisability of trying to estimate range at 90° is questionable. Most pilots have difficulty estimating angle off on beam attacks. If you are at the correct range but at 100° angle off, the high rate of closure results in a 500 ft. range error by the time you get to 90°. It is better to get on a base position that helps you get in range at the desired angle off.

A good base position for this particular attack is about one mile to the side, 1000 ft. above and 30° ahead of the tow airplane. From this position on a parallel course to the target, make a fast turn toward it and reverse the turn just prior to the 90° angle off position. From there on in, apply the proper deflection allowance and you should get to the desired firing position.

Here is one method of establishing a base position. From a position directly under the tow airplane, turn 30° and fly for 30 seconds at 300 mph and climb 1000 ft. above the tow plane. You arrive at a position one mile to the side and 30° ahead. Turn back 30° so you

parallel the target's path; then you are ready to start the pass. After following this procedure a time or two, you can recognize the position without going through the procedure.

This attack is only one of many possible; but whichever attack you choose, stick to it until you get results. Analyze each attack. If you find you cannot turn with the target, you were too close at 90°. Try turning a little faster from the base position. If you needed only a gentle bank to follow the target from 90° to astern, you were out of range. Try making the first turn a little slower.

When you find a pass that feels right, repeat the same one until you can assess your film and definitely prove yourself right or wrong. Then you will get good gunnery scores in practice—more than that in combat.

CAMERA FIRING EXERCISES

"Fly the Sight"

Every successful football team scrimmages with its freshman team. The freshmen run through the same plays which will be used by next week's opponents. Camera exercises are your scrimmage preparation for combat. Make these controlled conditions as similar as possible to reported tactical conditions. In this way you will learn to recognize combat opportunities. This will teach you to recognize and break off impossible attacks before you get into a position from which you cannot return the enemy's fire.

Camera exercises are as beneficial as actual air firing practice. They enable you to simulate combat speeds and maneuvers impossible with towed targets.

Know the sight pictures that result in hits before you go on a mission. Try to get these pictures. Assess your film and get an accurate analysis of your ability.

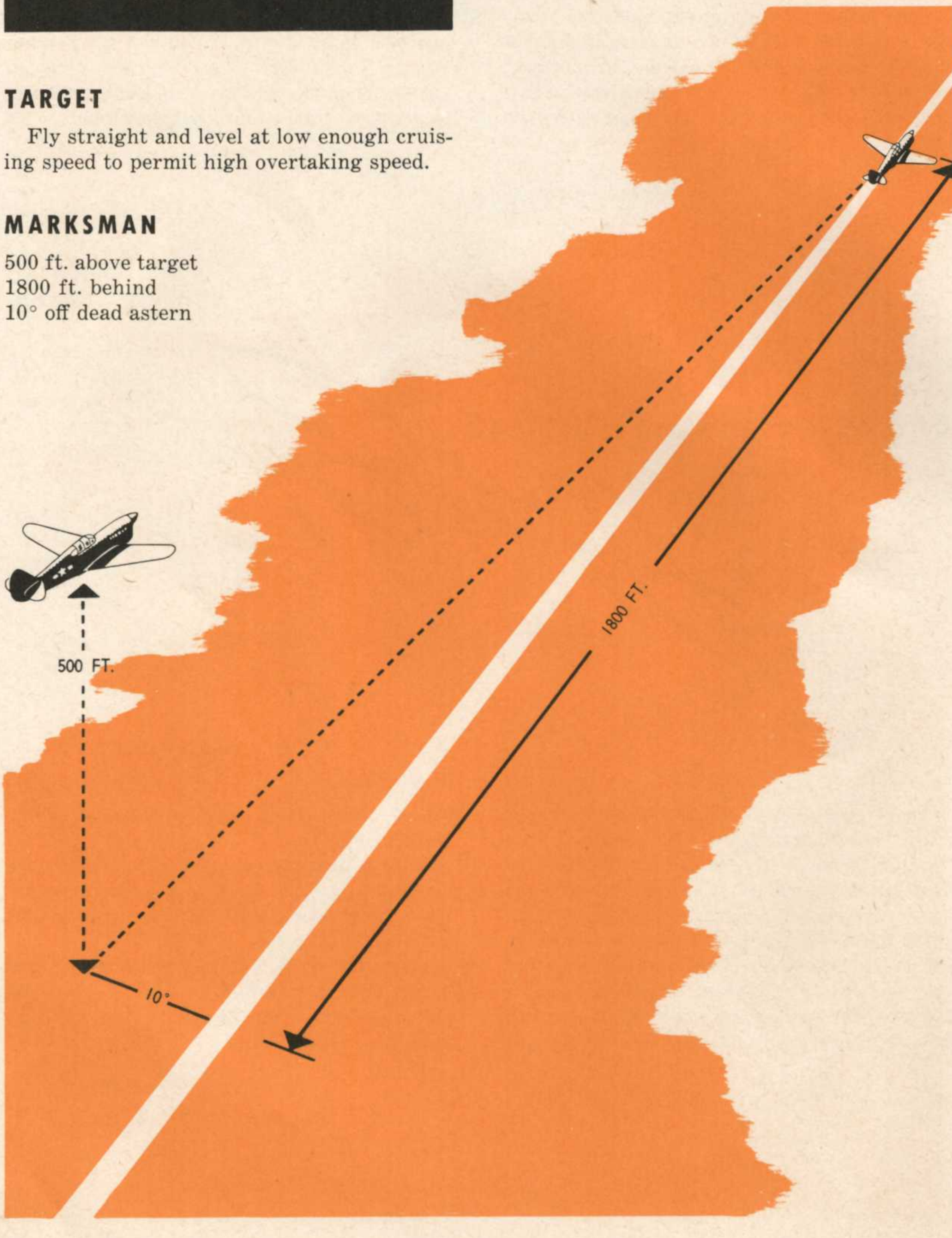
EXERCISE 1
RANGE ESTIMATION

TARGET

Fly straight and level at low enough cruising speed to permit high overtaking speed.

MARKSMAN

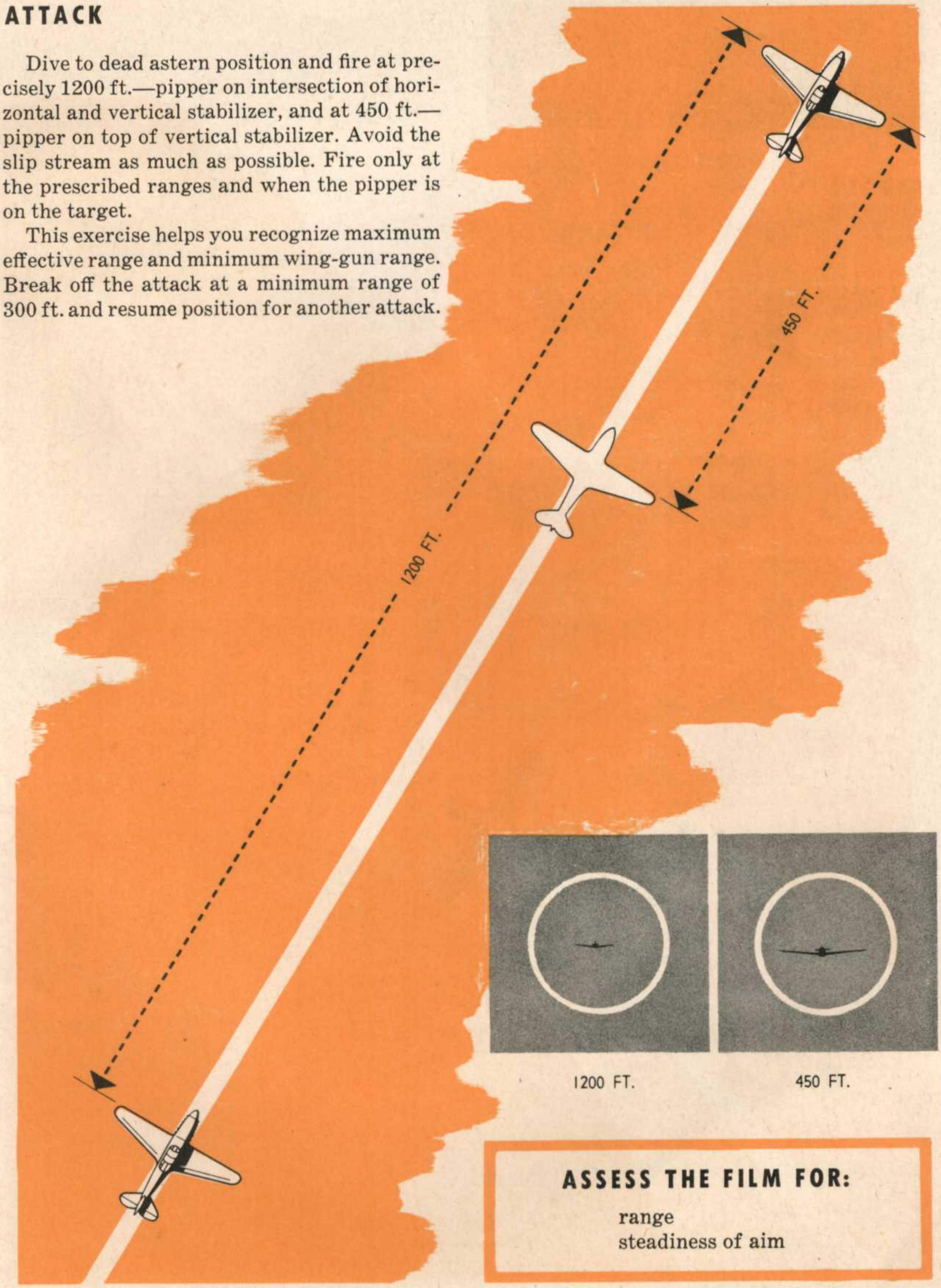
500 ft. above target
1800 ft. behind
10° off dead astern



ATTACK

Dive to dead astern position and fire at precisely 1200 ft.—pipper on intersection of horizontal and vertical stabilizer, and at 450 ft.—pipper on top of vertical stabilizer. Avoid the slip stream as much as possible. Fire only at the prescribed ranges and when the pipper is on the target.

This exercise helps you recognize maximum effective range and minimum wing-gun range. Break off the attack at a minimum range of 300 ft. and resume position for another attack.



1200 FT. 450 FT.

ASSESS THE FILM FOR:

range
steadiness of aim

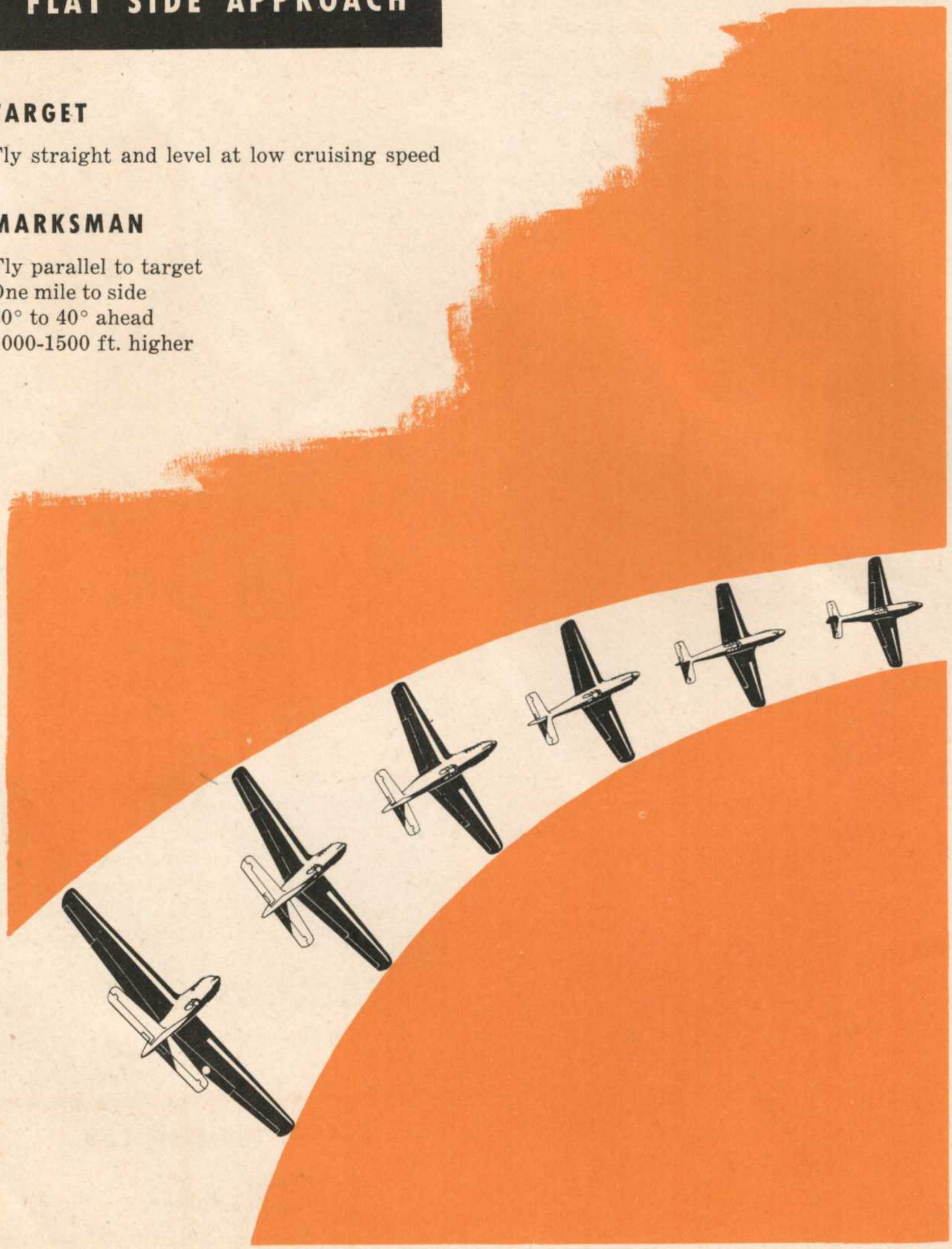
EXERCISE 2
FLAT SIDE APPROACH

TARGET

Fly straight and level at low cruising speed

MARKSMAN

Fly parallel to target
One mile to side
30° to 40° ahead
1000-1500 ft. higher



ATTACK

Make a smooth turn towards the target's line of flight in a gradual dive. Have sufficient power to approximate harmonization speed—about 275 mph.

Pick up the target at 90°, out of range. At the same time, reverse your turn and keep the pipper enough ahead of the target to allow the necessary deflection for the angles off that develop. Know the maximum angle off at which you can open fire with adequate deflection and still see the target over the fighter's nose. You must know the minimum range for this angle off at which you can make a fast enough turn to hold the required lead.

Knowing these factors, time the rate of turn reversal at 90° so you arrive at the desired angle off and range. In this way you can accurately deliver the highest concentrated fire.

Fire only when you are getting the correct sight pictures. Break away down and resume position for another attack.

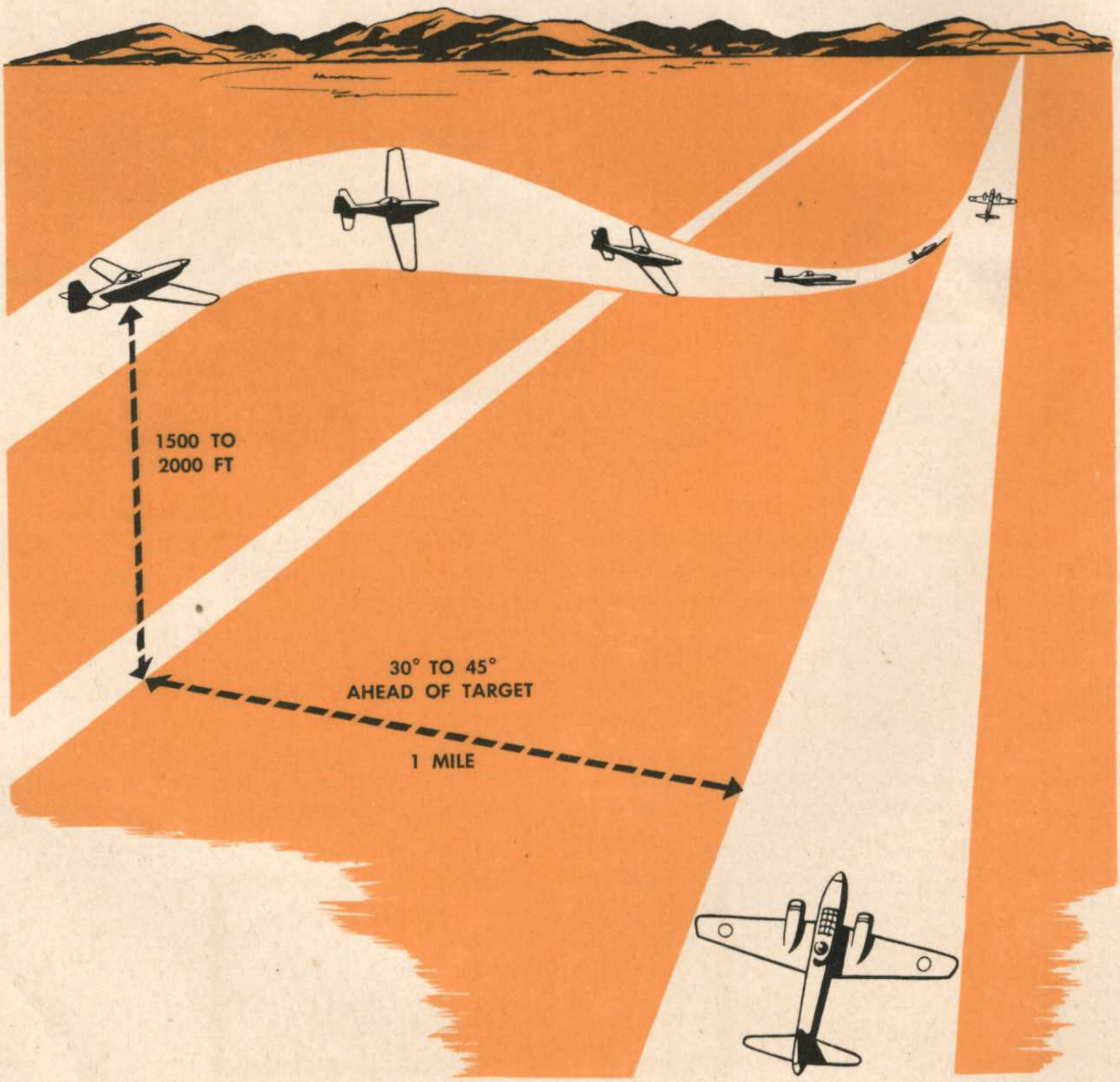
ASSESS 50 FT. OF FILM FOR:

range
alignment
deflection allowance

EXERCISE 3
90° HIGH SIDE APPROACH

Fly the high side approach the way you did the flat side—with one important exception. Make a nose-high turn toward the target from an altitude of **1500** ft. to **2000** ft. above the target, gradually lowering the pipper to the target's flight line as you reverse the turn at 90°. If you lower the nose too soon, you will wind up in making a flat side approach.

Review the preceding exercise before starting high side practice. The faster rate of closure requires even greater precision and timing in the turn reversal.



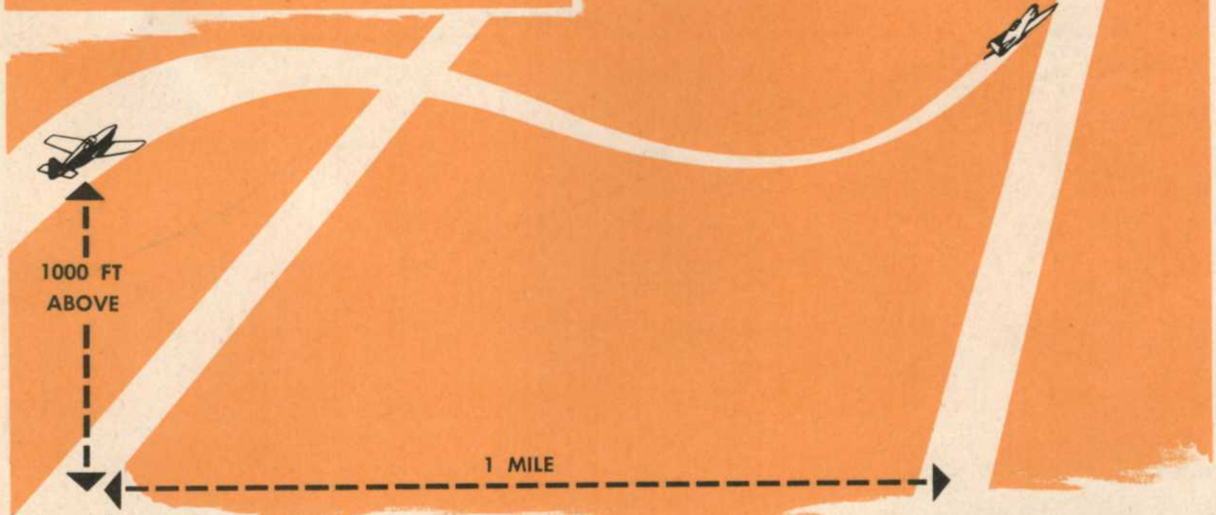
EXERCISE 4
90° LOW SIDE APPROACH

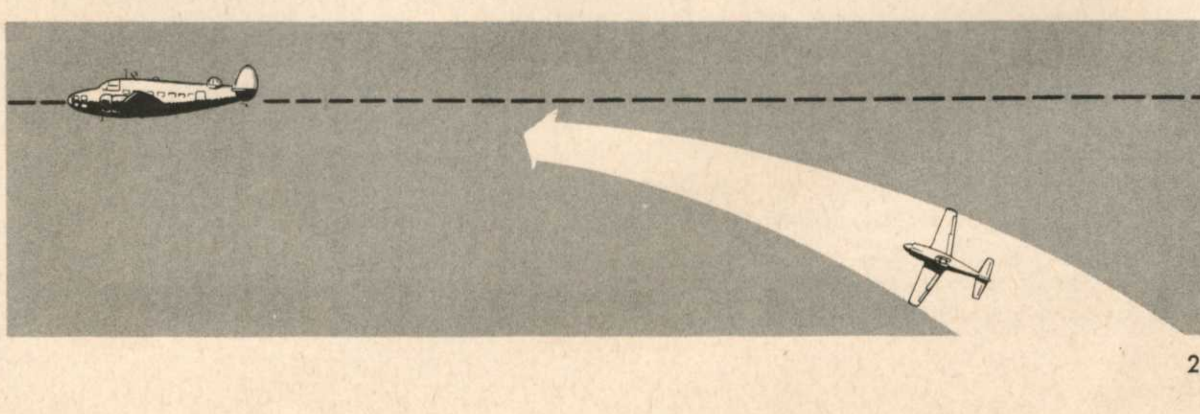
Space yourself about one mile to the side, 1000 ft. above and 30° to 40° ahead of the target. Turn toward the target, peeling off smoothly to about 500 ft. below its altitude. You should be able to fire from a 20° to 30° climb at 1200 ft. range, 50° angle off. Your original dive enables you to maintain satisfactory airspeed in the climbing curve of pursuit.

Cease firing if alignment, range or deflection become unsatisfactory. Break away down and resume position for another attack.

ASSESS FILM FOR:

range
deflection allowance
line of flight





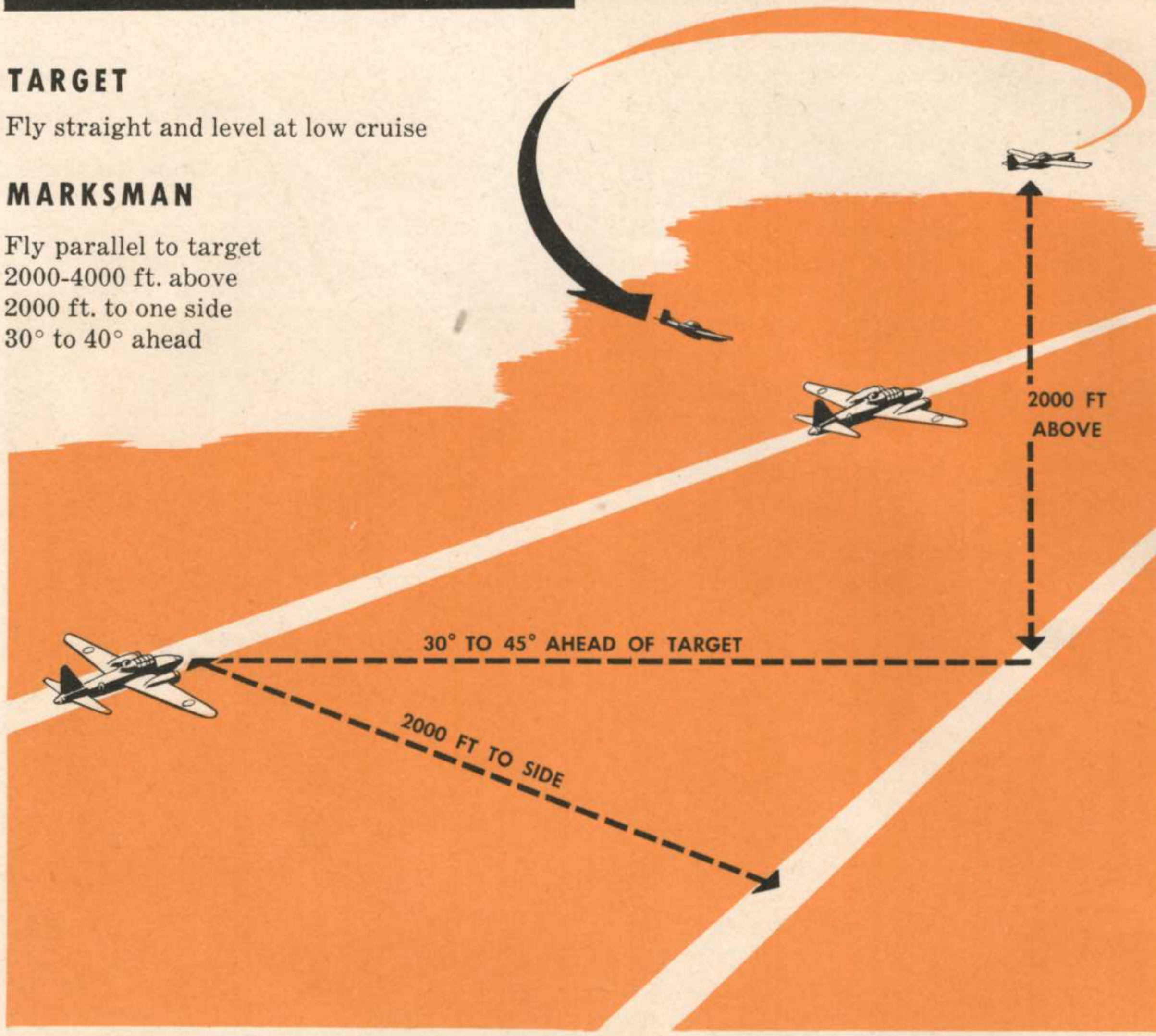
EXERCISE 5
OVERHEAD APPROACH

TARGET

Fly straight and level at low cruise

MARKSMAN

Fly parallel to target
2000-4000 ft. above
2000 ft. to one side
30° to 40° ahead



ATTACK

Start a 180° turn toward the target, reduce power and execute a nose-high half roll into a vertical dive through the target's line of flight. Pull the nose ahead to the maximum radii lead possible over the nose. Hold this deflection until the angle off and range are reduced to open-fire conditions. Decrease the deflection as the angle off decreases, breaking off at about 30°.

Cease firing and recover by **releasing the back pressure** and diving behind the target. This gives you a fast break, saves you from a bomber's tail gun, and eliminates the possibilities of collision.

The **absolute minimums** for this practice attack are 30° angle off, 600 ft. range. This attack is highly operational. It can be used effectively even in the face of top turrets because of the complex sighting problems involved for any turret to fire at large angles off. It is the most difficult attack to execute at high altitude and cannot be practiced at too low an altitude.


IF YOU LOSE SIGHT OF THE TARGET, DO NOT ATTEMPT TO PULL OUT AS THIS WILL RESULT IN A COLLISION
PUSH FORWARD ON THE STICK AND DIVE BEHIND THE TARGET

EXERCISE 6
HEAD-ON APPROACH

TARGET

Fly straight and level at low cruising speed

MARKSMAN

Two miles ahead and on parallel course
500 ft. above
3000 ft. to side

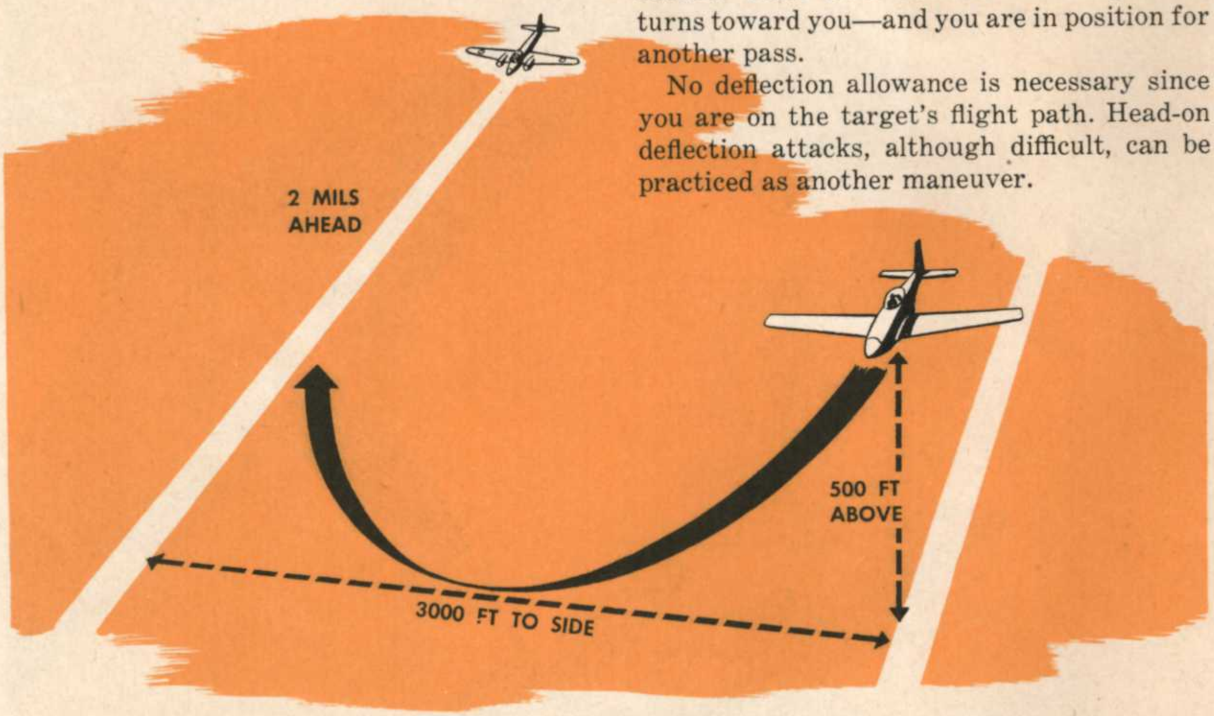
ATTACK

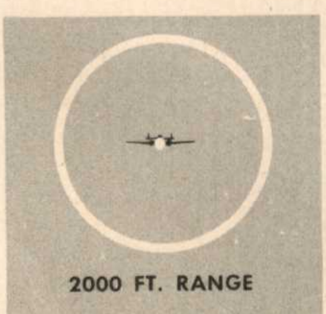
Make a 180° turn and get on the exact line of target flight. Open fire at 2000 ft. range with pipper on target's nose. Don't fire when the alignment or range is incorrect. Fire to a MINIMUM RANGE OF 600 FT. AND BREAK AWAY DOWN.

Be careful! The rate of closure is very fast. The initiative for the breakaway rests entirely with the marksman. You must strictly adhere to a **minimum** range of 600 ft.

After breaking off the attack, turn 45° to either side and fly for a few seconds on this course. Then turn toward the target—he turns toward you—and you are in position for another pass.

No deflection allowance is necessary since you are on the target's flight path. Head-on deflection attacks, although difficult, can be practiced as another maneuver.





2000 FT. RANGE

600 FT. RANGE

ASSESS FILM FOR:

range
alignment

WARNING

BREAK AWAY DOWNWARD AT AN ABSOLUTE MINIMUM RANGE OF 600 FT.

SECTION 2 Ground Attack

The fighter airplane's importance in modern warfare will continue to increase as new and better weapons are developed. Over-specialization is the only thing that can hinder its versatility and adaptability to mobile warfare. If expert rocket firing, dive bombing, strafing, and aerial gunnery each requires specialists, the fighter airplane's full potentialities will never be realized. The only way to avoid such individual specialization is by simplifying the use of each weapon until the pilot can be an expert with all of them.

The wing line method of hitting ground targets with rockets, bombs, and guns is designed to avoid this specialization. It is a standardized method of getting hits with three weapons that have entirely different ballistic characteristics. It incorporates the

same fixed optical gunsight you use in aerial gunnery, although a minor addition is necessary for dive bombing. This means you can go out on a ground support mission and engage in air-to-air combat at a moment's notice, without having to re-adjust the sight. (See Wing Lines.)

This section presents the problems involved in hitting targets with all three weapons. Then it points out how and why the wing line system solves these problems, and finally, tells you how to fly the wing line.

PROBLEMS

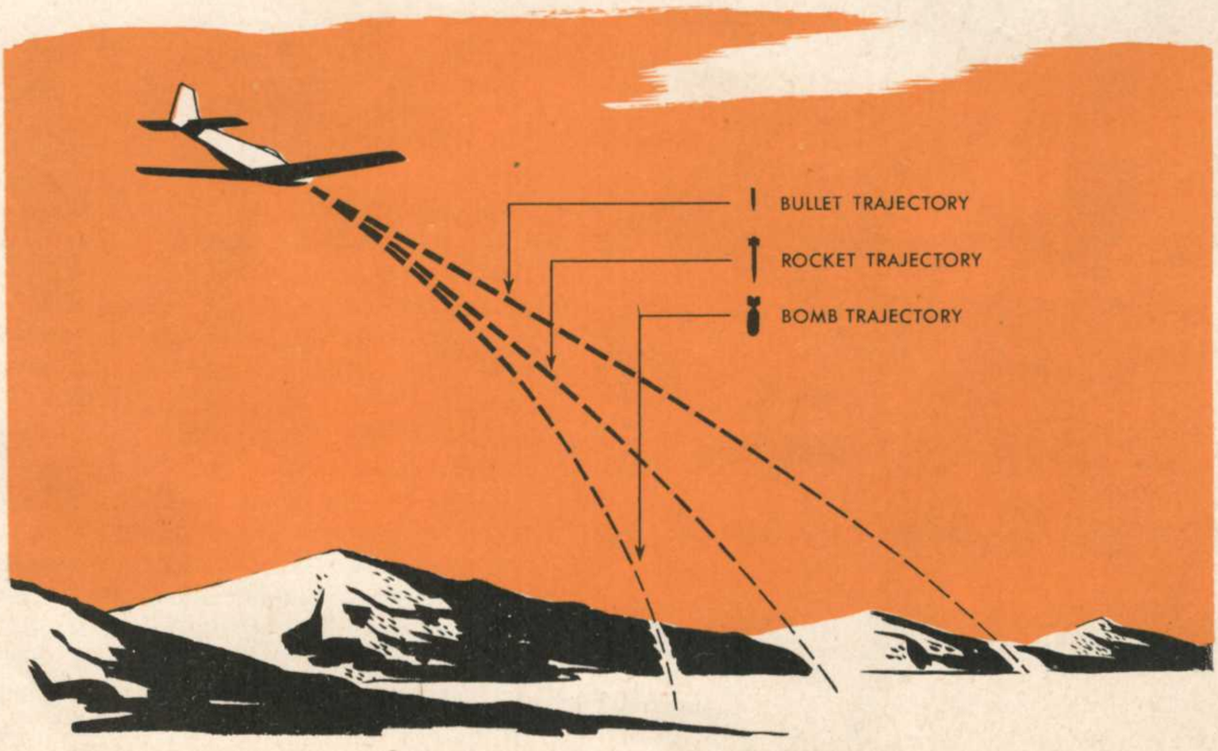
As has already been mentioned, a fighter's rockets, bombs, and machine guns have entirely different ballistic characteristics. Machine gun bullets have a fairly flat trajectory within normal firing range because they reach 2700 ft. to 3200 ft. per second velocity at the muzzle. Since the airplane's speed contributes to the bullet velocity, the airplane's flight direction influences the bullets' flight path. If the airplane is not flying along the path the gun bore is pointing, the bullets deflect a little from the gun bore toward the airplane's line of flight.

Rockets are slower than bullets. They leave their launcher with only a fraction of their 1000 ft. to 1350 ft. per second (plus airplane speed) terminal velocity. They require from 0.7 to 1.4 seconds to reach maximum velocity, depending on the temperature of the propellant charge.

Although rockets may not be launched exactly along the airplane's flight path, fin stabilization causes them to deflect immediately toward this path. Therefore, terminal velocity develops almost along the same line. As a result, rocket trajectories are extremely sensitive to airplane flight attitudes, speed changes, dives, maneuvers, etc., creating difficult sighting problems.

Bomb trajectories are completely different. Their only propellant is airplane speed, so gravity affects them more than it does rockets and bullets over the same range. Except for gravitational and windage effects, bombs continue along the launching airplane's flight path.

The accuracy of all three weapons depends on the firing or releasing range, the dive angle, and the airplane's attitude. It is a proved fact that even the best and most experienced pilots cannot consistently estimate this all-impor-



tant slant range and dive angle. But they can control the airplane's speed and, therefore, the airplane's attitude. With this in mind, the wing line method has been devised to help you get to a slant range, angle of dive, and attitude that result in hits. It affords versatility in that you can attack from any direction, altitudes of 2000 ft. to 11,000 ft., and dive angles of 20° to 60°.

Combining rockets and machine guns or bombs and machine guns works well. As yet, there is no practical method of using all three weapons in the same dive without sacrificing accuracy.

Get these ideas firmly fixed in your mind. Wing line attack execution, although simple, requires a high degree of pilot proficiency. It is no more difficult or dangerous than other training phases. Follow training methods similar to those suggested in this manual, no matter how good you are. The wing line method can get excellent hits—that has been proved beyond doubt. Now it is up to you!

HOW WING LINES SOLVE THE PROBLEMS OF GETTING THE AIRPLANE AT SPECIFIC RANGES, ANGLES OF DIVE, AND ATTITUDES

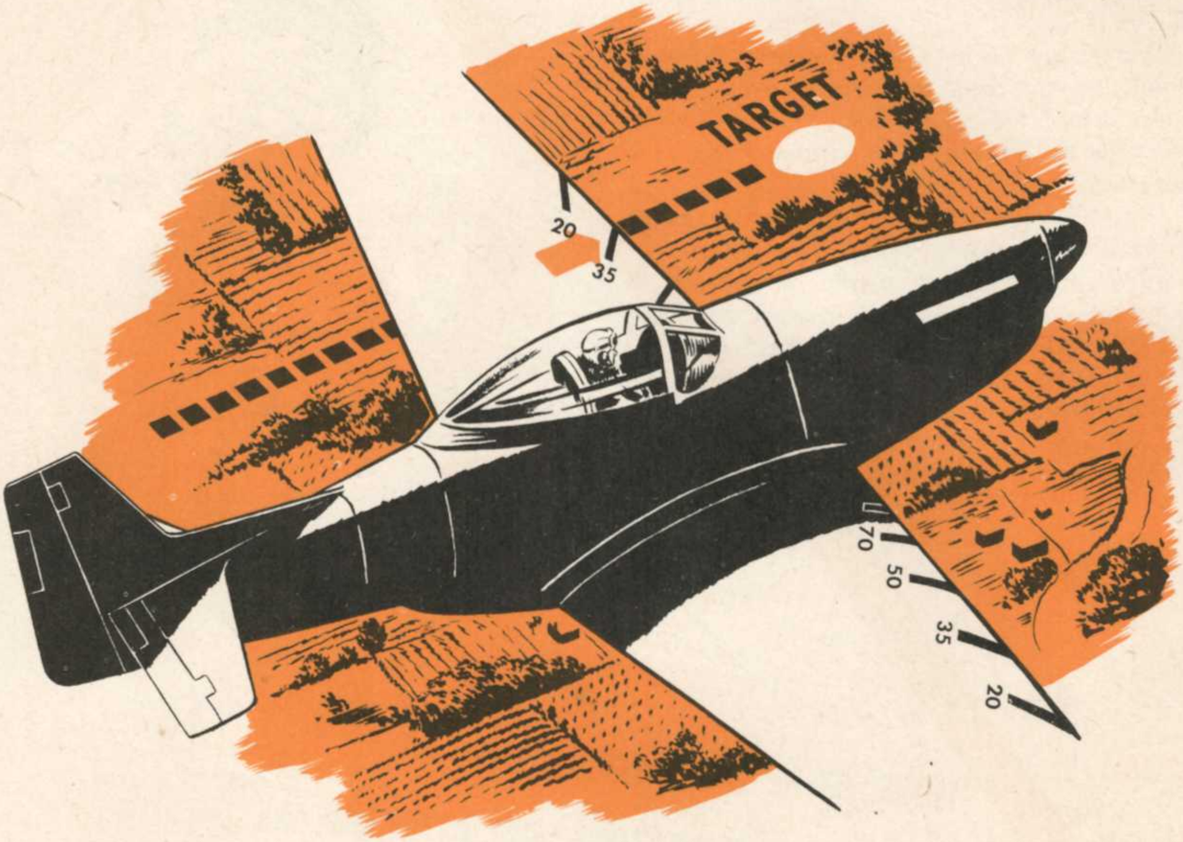
ANGLE OF DIVE

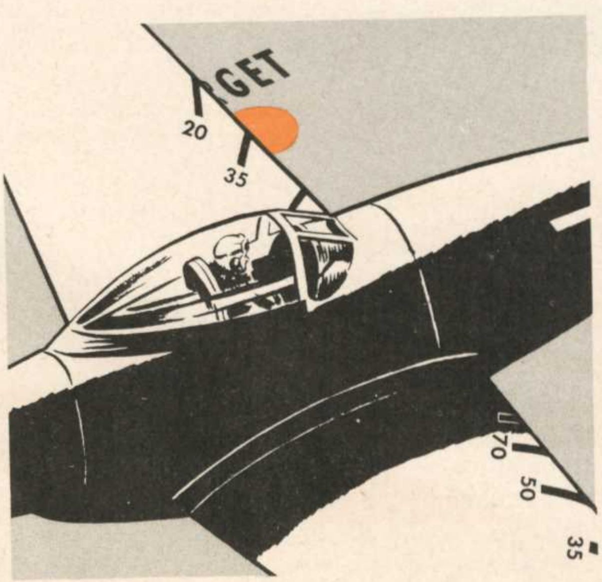
Wing lines are markings or lines on the wings' leading edges. They are positioned so the airplane is at a known angle from the target if the line appears to be touching the target when the airplane is straight and level. Each line is numbered according to the altitude at which you should start the dive.

For example: if you are at 5000 ft., use wing line No. 50. Fly straight and level and direct the airplane so this wing line approaches and

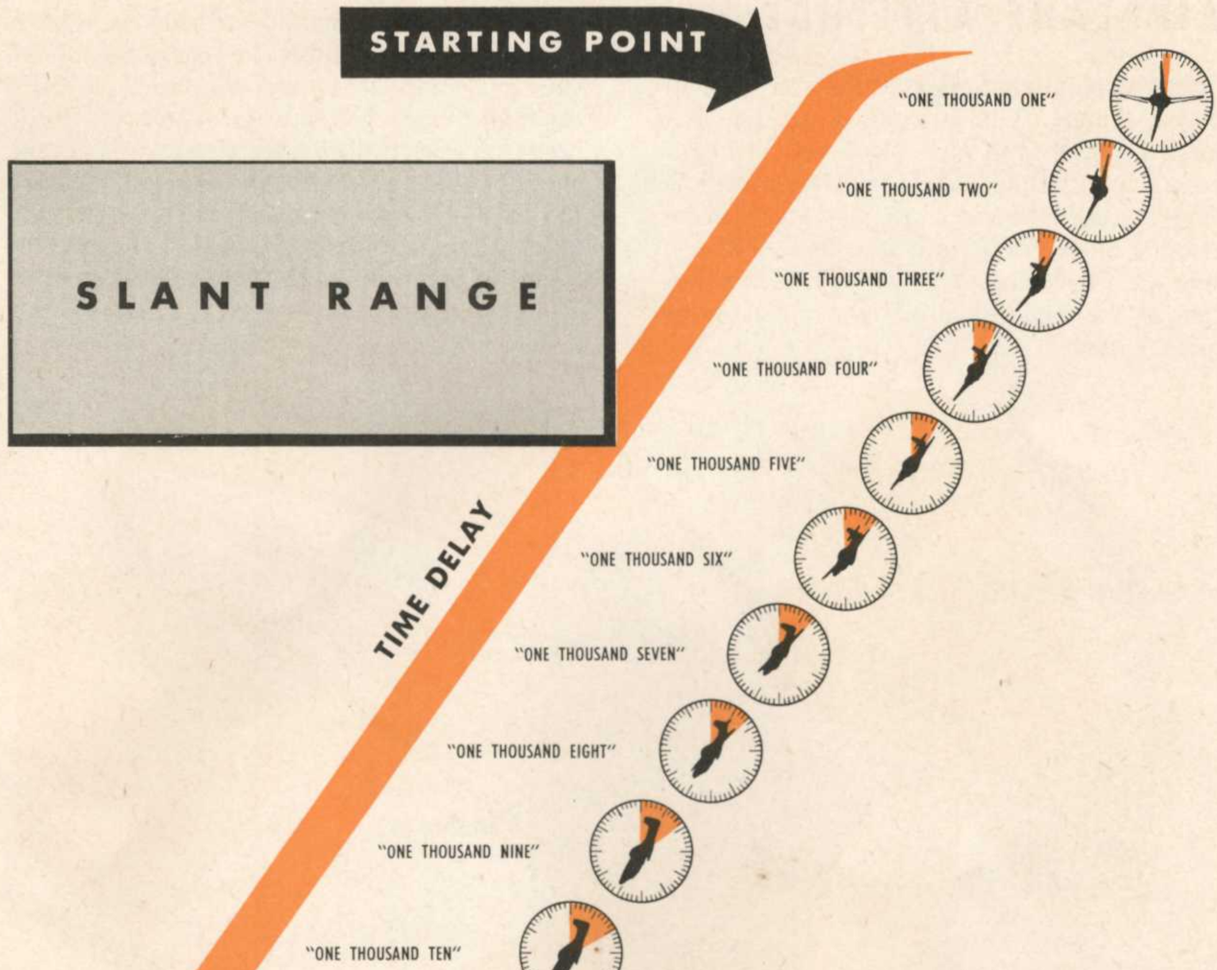
finally appears to touch the target. Make a diving turn to the target and the airplane is in a known angle of dive.

Wing lines are positioned to establish dives from 2000 ft., 3500 ft., 5000 ft., 7000 ft., 11,000 and are correspondingly numbered 20, 35, 50, 70, etc. The resulting dive angles range from 20° to 60° (see "Wing lines").





SLANT RANGE



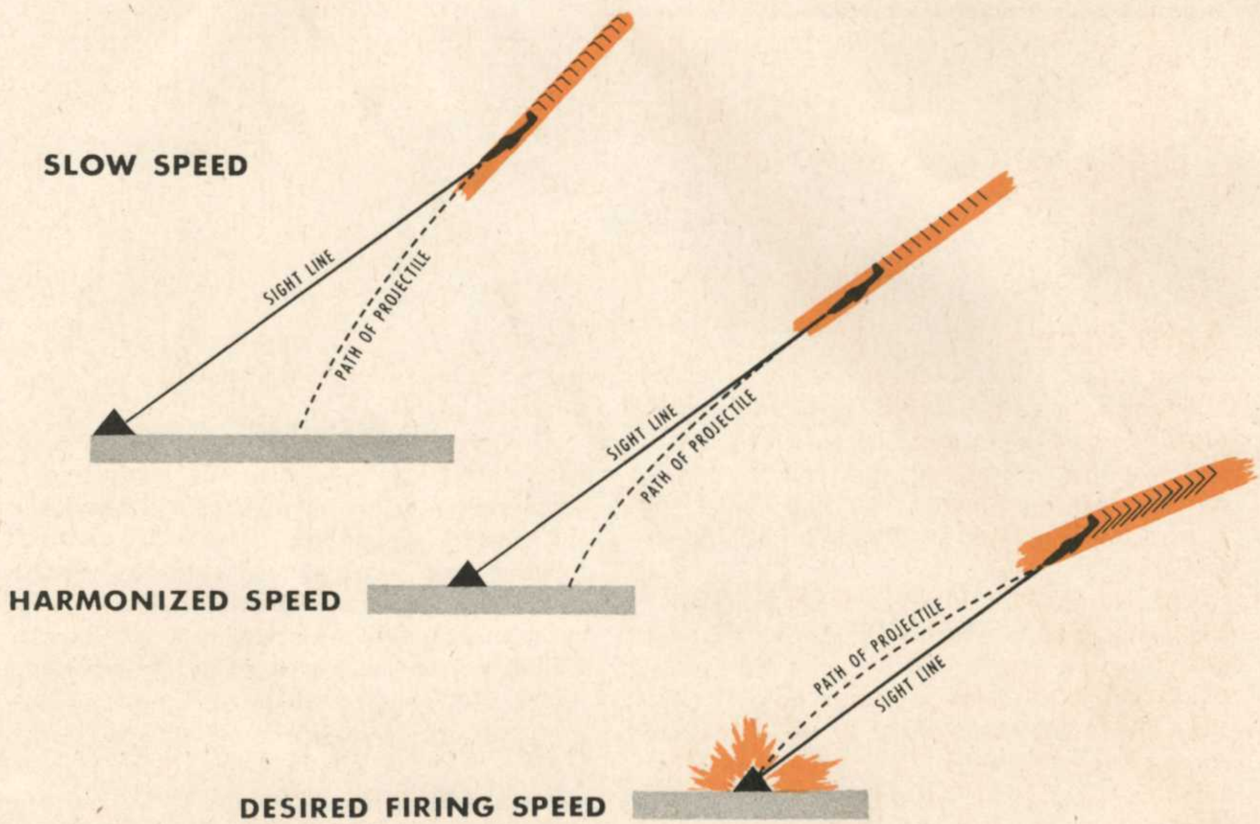
Slant range is the air line distance from the airplane to the target. The airplane arrives at specific ranges after definite time lapses. Therefore, you can get to desired ranges using a time delay—by counting the number of seconds the airplane has been in the dive.

For actual ranges using specific Wing Lines and time delays see chart in back of manual.

AIRPLANE ATTITUDE

The airplane changes attitude with each airspeed change. The amount of change is a known factor and the necessary projectile releasing attitude has been determined. By entering each dive at a specified airspeed and staying on the dive for a specified number of seconds, the fighter arrives at the desired attitude at the same time it arrives at the desired firing range.

Range, dive angle, and attitude have been broken down for explanatory purposes. That they are interrelated and dependent on each other is obvious. Extensive research and flight tests have been necessary to properly locate the wing lines for easily remembered altitudes that result in a good variety of dives. The airplane attitude and slant range at firing position, the required entry airspeed and number of seconds to get to this position, are all products of precise computations.



THE RESULTS:

1. A standardized training method that increases proficiency in establishing slant range and dive angles.

2. A resulting proficiency applicable to tactical methods

3. Pilot knowledge that will be useful when computing sights for ground attack and other new aids are developed.

4. A system incorporating the fixed optical gunsight with a zero sight setting and acceptable harmonization.

5. A simplified method that only requires an ability to measure time delay accurately, a knowledge of target altitude, and control of the airspeed in straight and level flight.

Your individual success using the wing line system depends on your ability and training, and on the proper harmonization of the sight and weapons.

FLYING THE WING LINE

Approach

Select a wing line corresponding to your altitude above the target. Accurate hits result only when you initiate the dive from the exact altitude required for that wing line. Under no circumstances should you begin an approach at a lower altitude.

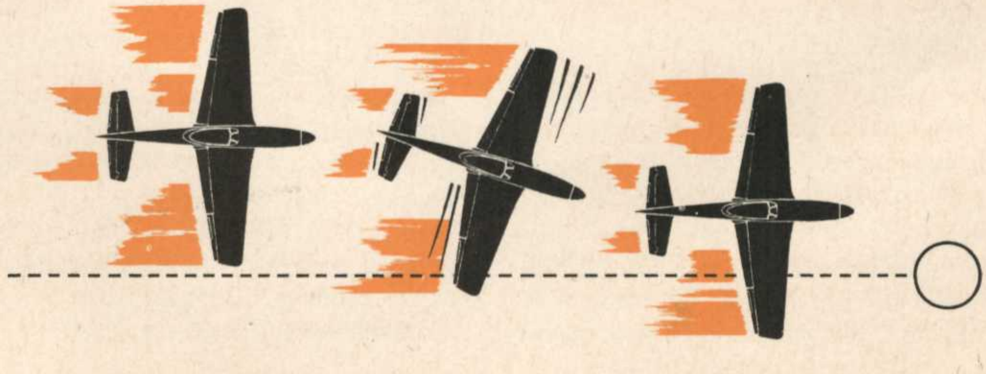
Fly straight and level at the required airspeed, trimmed for high cruise. Direct the approach so the wing line will eventually touch the target. Do this by watching the path the wing line is making over the ground. Making corrections by keeping the wings level and skidding the airplane with the rudder has been proved more accurate than banked turns.

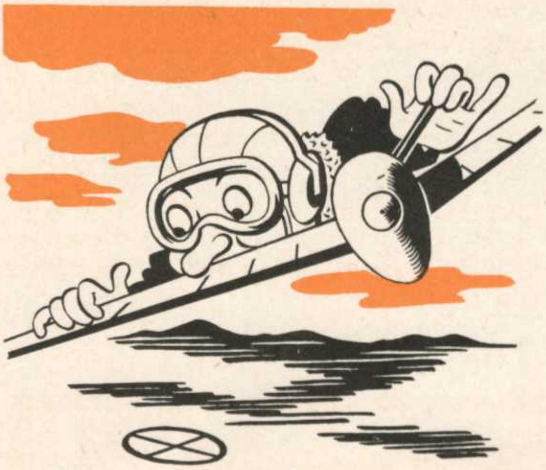
Most pilots have a tendency to drop the inside wing for more visibility. Watch out for this error because the resulting dive angle will be too steep.

The approach angle varies somewhat with each pilot because of different seating positions. Do not try to keep your head rigidly in the center of the cockpit. Turn it in a natural manner that permits good visibility. Other small variations in the approach pattern result because each type of fighter has a different visibility over the leading edge of the wing.

DIVING TURN

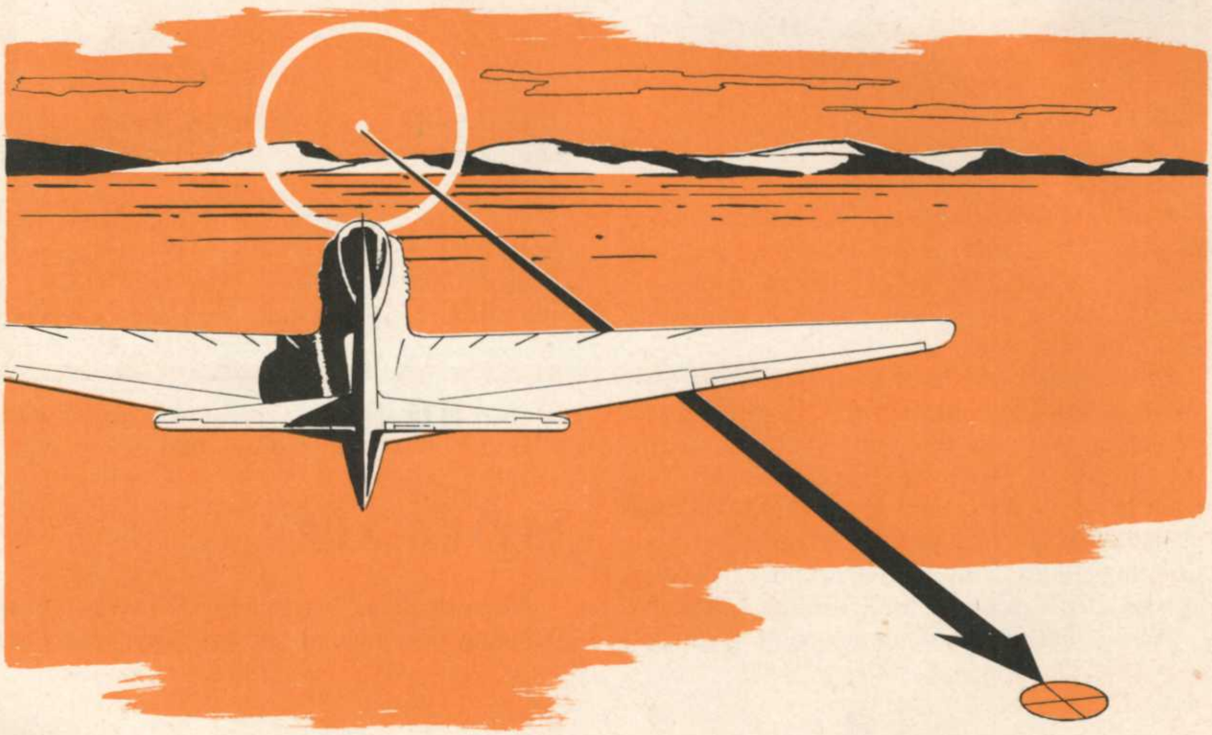
When the wing line touches the target, drop the wing sharply and pull the pipper from its





position on the horizon **straight to the target.** Begin counting off the seconds the moment you drop the wing. You are now committed to a dive angle and direction, so **do not try to play the turn.** This results in erratic dives, especially at high altitudes. It nullifies the time delay and makes proper wind allowances almost impossible. All playing must be done on the approach, not in the turn or on the dive.

Roll out of the turn on the desired aiming point. Pulling the nose from the horizon to a position under the target, and then bringing the pipper up to the target, shallows the dive. This is called undershooting and must be avoided. Bring the pipper from the horizon to the target in a **straight line.** Complete the roll-out on about the "nine" second count. Don't worry about minor variations in the rate of this turn because they balance out. For example, an eight-second turn results in a greater roll-out range, but acceleration gets the airplane to the desired firing range.



DIVE

Fire the machine guns from the "eleven" to "thirteen" second count and launch rockets at "fourteen".

If the dive is not set up properly by the count of "eleven", go around. Attempts to change the wind allowance, approach direction, or angle of dive result only in misses. **You have committed yourself and it's too late to make changes.** Break off this dive and start another one, if necessary.

On a dive bombing run, aim with the depressed bombsight (sec. 6) and release bombs at the count of "sixteen."

Whatever the attack method, accurate hits

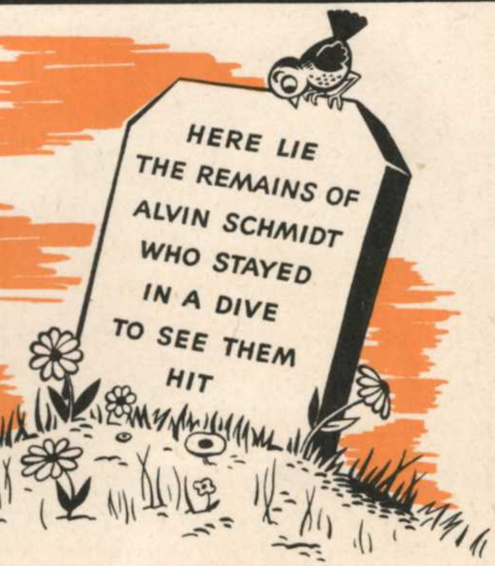
with rockets and bombs result only if the airplane remains in a constant dive for at least two seconds so it can settle down in its flight path. Each type of fighter accelerates at a different rate, but this slight variable is fortunately balanced out at firing range by the difference in attitude.

Test pilots recommend that trim tabs be set for high cruise. This streamlines the rudder and aileron tabs at 0° if the airplane is properly rigged. It is not a good idea to have the tabs protruding into the slip stream at 400-500 mph. Besides, it improves pilot technique to coordinate the left rudder in dives and the right rudder on the way back up.

Fly the airplane smoothly. **Do not slip or skid.** If you cannot dive without slipping or skidding, you might as well give up air-to-ground work. Accuracy is critically dependent on good flying.

DIVE RECOVERY

Make a normal pull out without delay. Strong, steady back pressure is more desirable than sharp or jerky tugs on the stick. **Do not delay the pull out to watch the rockets hit.** This is a natural and common tendency and can easily be dangerous, especially in the steeper dives.



THROTTLE SETTING

Use throttle settings that result in the following approach speeds:

P-38 — 250 mph on Wing line No. 20
P-51 — 250 mph on Wing line No. 20
P-47 — 240 mph on Wing line No. 20

From wing line No. 20 on up, decrease approach speed 10 mph for each successively higher wing line. Throttle technique in dives is a pilot problem. The manifold pressure builds up in the steeper dives, so coordinate the throttle accordingly.

THREE IMPORTANT SUBJECTS

The first is counting. Practice this cadence on the ground against a stop watch. Counting "one thousand and one, one thousand and two, one thousand and three," etc. is suggested. The importance of accurate time delays is best emphasized when you realize that an 18.0 second delay in some dives results in extremely low recoveries.

The second point is building up proficiency. You have to work up to the steeper dives and longer time delays. Practice the shallow dives and short time counts until your ability and confidence enable you to use longer delays and then steeper dives. You didn't expect to solo on your first flight, so don't expect to start wing line training at any place other than the beginning.

Finally, know the target altitude and set your altimeter at existing barometric pressures. It is possible to know approximate tactical target altitudes and exact training target altitudes.

CORRECTING FOR WIND OR TARGETS IN MOTION

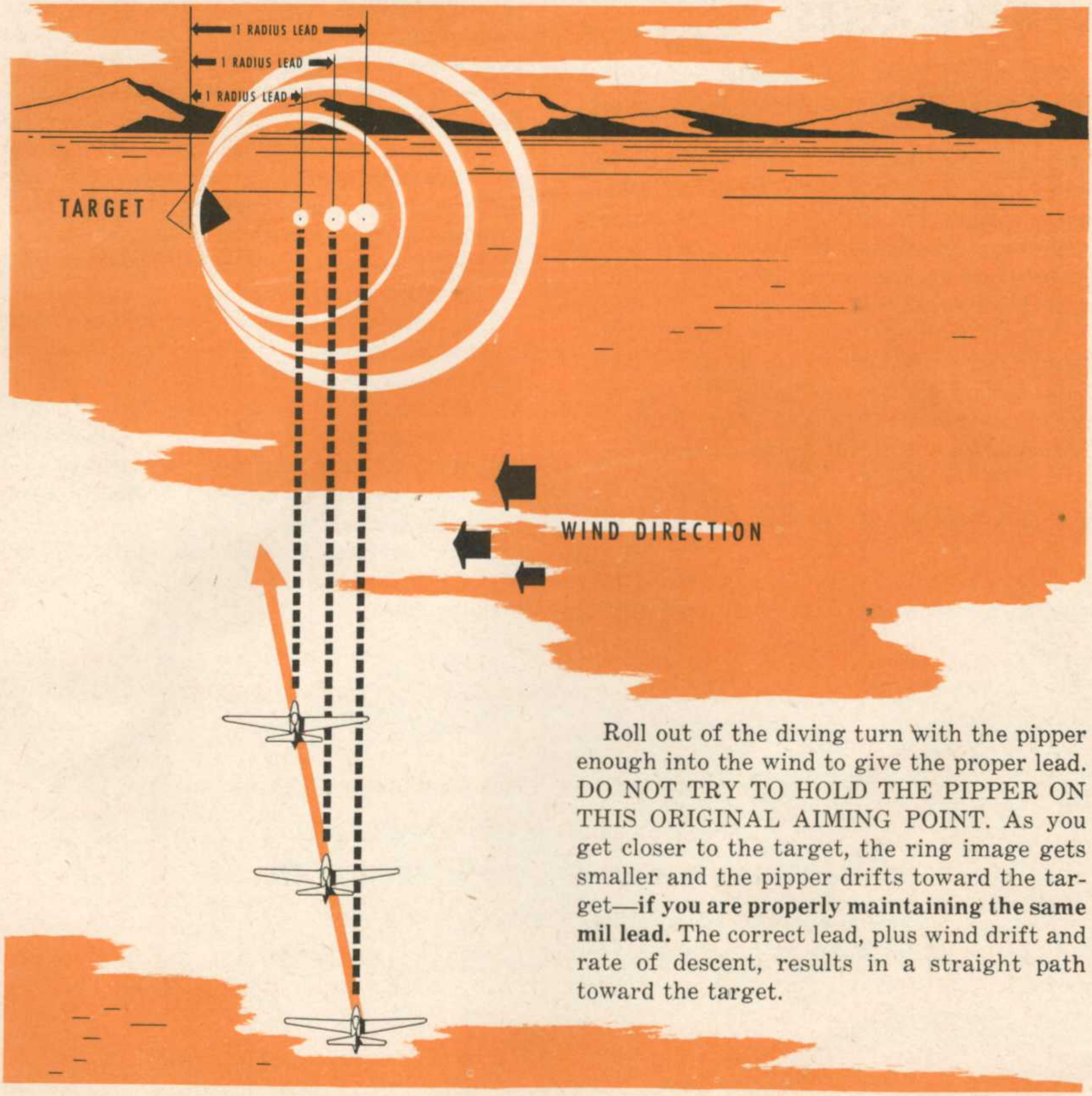
Measure lead allowance in ground attacks the same as in aerial gunnery. Leading for wind is necessary not so much because of the wind effect on the projectile, but because the air mass is moving the airplane as it dives. The released projectile follows the path the airplane has been making.

Deciding on the amount of windage correction is difficult. Actual windage correction is one-half mil per mph for machine guns, one mil per mph for rockets, and three and one-half mils per mph for bombs. However, the winds at altitudes through which you dive usually have higher velocities than surface wind. In most cases you can know only the surface wind velocity, so base your windage correction allowance on the following figures:

Machine Guns: Lead **one** mil per mph. Example—lead 25 mils or one-half radius for a 25 mph surface wind.

Rockets: Lead **two** mils per mph. Example—lead 50 mils or one radius for the 25 mph wind.

Bombs: Lead **five** mils per mph. Example—lead 125 mils or two and one-quarter radii for the 25 mph surface wind.



Roll out of the diving turn with the pipper enough into the wind to give the proper lead. DO NOT TRY TO HOLD THE PIPPER ON THIS ORIGINAL AIMING POINT. As you get closer to the target, the ring image gets smaller and the pipper drifts toward the target—**if you are properly maintaining the same mil lead.** The correct lead, plus wind drift and rate of descent, results in a straight path toward the target.

DOWNWIND DIVES

The pipper is short of the target, the wind blows the airplane toward the target and, as a result, you get a feeling of humping over as the dive necessarily steepens. This feeling is especially evident when dive bombing with the depressed bombsight.

Allow full lead even though the wind is not acting 90° to the airplane's flight path. The tail wind results in a decreased firing range and an increased dive angle, causing the projectile to overshoot unless you do allow full lead.

UPWIND DIVES

This attack feels comfortable because the wind "backs" the airplane away from the target, causing it to shallow out. The restricted radii lead over the nose of most fighters, combined with the necessity for large lead allowances, makes upwind dive bombing attacks practically impossible. However, you can fire rockets and machine guns effectively in moderate head winds.

As in downwind dives, allow full lead even though the wind is not moving 90° to the flight path. Otherwise, the shallowing dive, extending of firing range, and wind on the projectile will cause the projectile to fall short.

CROSSWIND DIVES

Crosswind attacks are more desirable than upwind or downwind attacks from a standpoint of accuracy, consistent dive angles, and slant ranges. It is easier to apply large lead allowances to the side of the target than it is above or below because of most fighter's visibility limitations.

Roll out of the diving turn with the correct mil allowance upwind. Do not follow your old habit of flying the pipper. Fly the sight picture and keep the target-mil lead relationship constant. Assess camera film to correct improper wind allowance habits.

Lead allowance using rockets and machine guns is substantially less than that required for bombs. In long dives this would necessitate a slight roll to hold the lead. However, you fire the machine guns almost as soon as you roll out of the diving turn and rockets are extremely sensitive to airplane maneuvers, so dive with wings level and do not roll.

Do not attempt dive bombing until you can hold a constant lead relationship in the easier strafing dives.

ROCKET FIRING AND DIVE BOMBING ACCURACY DEPENDS ON YOUR FLYING ABILITY. YOU CANNOT PREDICT WHERE THE ROCKETS OR BOMBS WILL STRIKE UNLESS THE AIRPLANE STAYS ON A STRAIGHT COURSE FOR AT LEAST TWO SECONDS.

TRAINING RECOMMENDATIONS

1. Make camera passes until you attain desired proficiency. Maximum dive angle error is plus or minus 2°. The predetermined dive angles resulting from the wing lines are listed on pg.

2. Plus or minus 400 ft. from the desired firing range is the maximum allowable range error.

3. Evaluate slant ranges and dive angles by assessment.

4. You must be able to make a 60° dive with complete pilot ease.

It takes 100 to 150 dives to reach this proficiency. Divide these dives equally among the wing lines, and alternate right and left hand passes. Close supervision by qualified ground

personnel is an absolute necessity. They can use a dive angle and a slant range indicator, such as the harp, to check pilot proficiency. They must employ the radio to make immediate corrections of dive or technique errors. Film assessing (pg.51) is an excellent method of checking proficiency. Absolute consistency in pilot technique and aerial discipline must be obtained before advancing to the next phase.

VARIATIONS

The wing line method of ground attack is not the answer to all problems. Recommended wing lines, altitudes, speeds, and time delays are predicated on training conditions existing when this manual was prepared. It may be necessary to modify one of these factors. Bombs have different trajectories and you may have to make a test run to learn the amount of these variations. They won't be very great, and a slight change in time count will probably correct the error.

A rocket's trajectory changes with the temperature because the propellant temperature influences its speed of burning, and therefore the rocket's speed. If you are operating in extreme temperatures, run a test mission and vary the time count slightly to correct apparent errors.

In all cases, good judgment and technique in applying the fundamental ideas of wing line positioning and time delay are necessary to obtain satisfactory results.

Pilot Responsibility

Be very careful when rockets are being placed on your airplane. Be sure the proper precautions are observed by all loading personnel as well as yourself. Read sec. 7 for further information on this subject.

LOW LEVEL ATTACKS

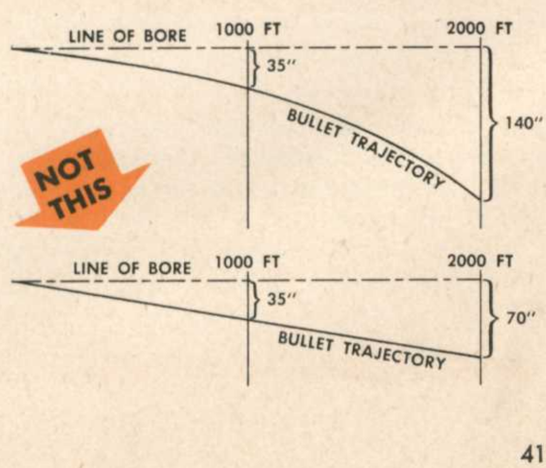
Low level strafing and skip bombing are other methods of ground attack. The desirability of these attacks depends on tactical considerations. Information in this section will help you improve your accuracy.

ON-THE-DECK STRAFING

It is easier to sight machine guns on ground targets than on aerial targets. Maximum effective firing range is greater because there is practically no deflection problem. Trains, trucks, etc., usually halt when attacked so their personnel can reach cover. Therefore, getting hits seems to be limited only by your ability to put the bead on the target and to make small wind corrections. THIS IS TRUE IF THE BULLETS ARE ALONG THE SIGHT LINE. The question now is: "When are the bullets along the sight line, and when are they not?"

They most certainly are NOT when the airplane is slipping or skidding. Such induced bullet errors are angular errors and increase with range. For example: at 340 mph, a 4° skid deflects the bullets 11 mils from the sight line. At 1000 ft. range, they miss the target by 11 feet; at 3000 ft. range, they miss it by 33 feet.

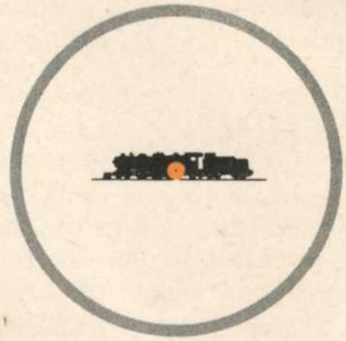
At long ranges, the bullets are NOT along



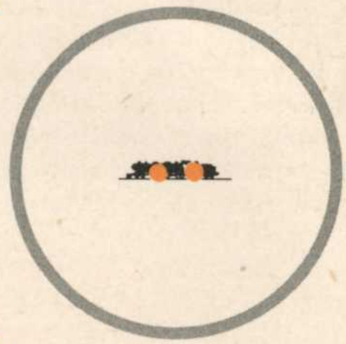
the sight line because of gravity drop. Bullets are subjected to the force of gravity as soon as they leave the muzzle. The amount of drop depends on the bullets' velocity and the distance they have to travel. Since the bullets are slowing down from the time they leave the muzzle, they take more time to cover the second 1000 ft. than they did the first. A standard bullet trajectory from level flight looks like this:

At long ranges, bullet patterns are NOT along the sight line because wing guns are harmonized to converge at short range, and then separate.

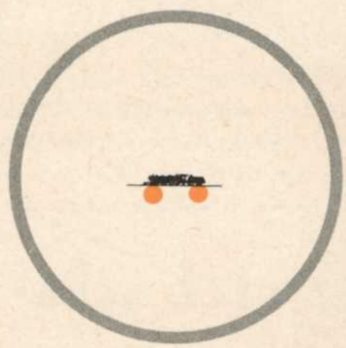
At 1200 ft. range, the bullet grouping around the pipper looks like this.



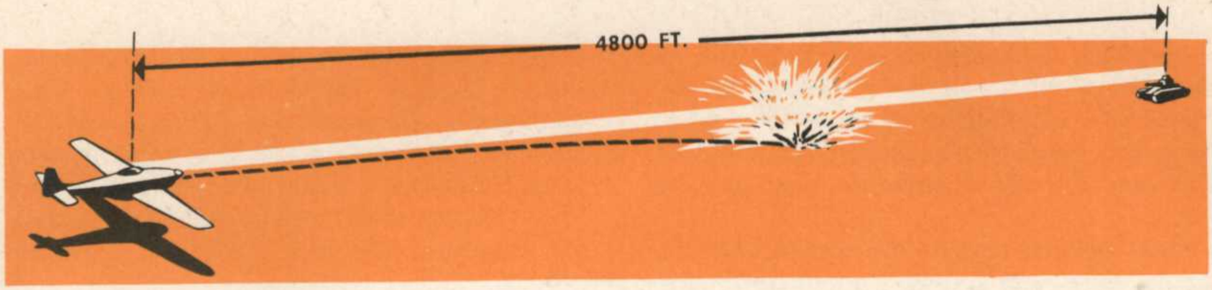
The bullets do not drop below the sight line until they reach about 2000 ft. range.



At 3000 ft., they are still within four mils, which is about as close as you can aim.



But at 4800 ft., they are 60 ft. below the sight line, although only a little more than ten mils low.



The bullets don't appear to leave the sight line much over long ranges, but you will probably miss a long range target for three reasons:

1. The extreme difficulty of aiming accurately at long ranges.

2. Pattern spread caused by converging harmonization of wing guns and bullet dispersion of all guns.

3. If the deck is eight feet below the guns and you aim directly at a target 4800 ft. away, the 60 ft. gravity drop does not mean the bullets fall 60 ft. short and then possibly ricochet into the target. As you can see from the illustration, they fall 1800 ft. short.

This analysis indicates that range is the main factor in determining whether or not the bullets are on the sight line. The difficulty of sighting accurately at long ranges, and estimating ground target range, limits the possibility of making sighting allowances. Tactical situations often necessitate opening fire at excessive ranges, but the real damage is inflicted at close range. If possible, don't break off the attack until you get in close. And don't try to shoot up everything in sight in one attack. Pick out one specific target and concentrate on only that one.

PRACTICE RANGES

A strafing range that enables safe firing from the deck is more practical than the standard ground gunnery range. If you do use the standard range, incorporate wing line No. 20 and a 12 second delay in the firing pass.

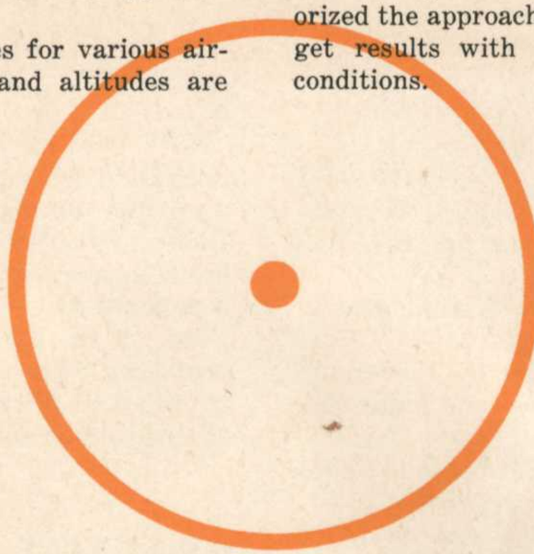
SKIP BOMBING

Skip bombing accuracy is predicated on releasing the bombs at close range from a low altitude. Delayed action bombs permit the fighter to clear the blast. Eleven second delayed fusing for ground targets and five second fusing for water targets are minimum requirements.

Since this attack requires delayed fusing, the target must be large enough to stop the bomb.

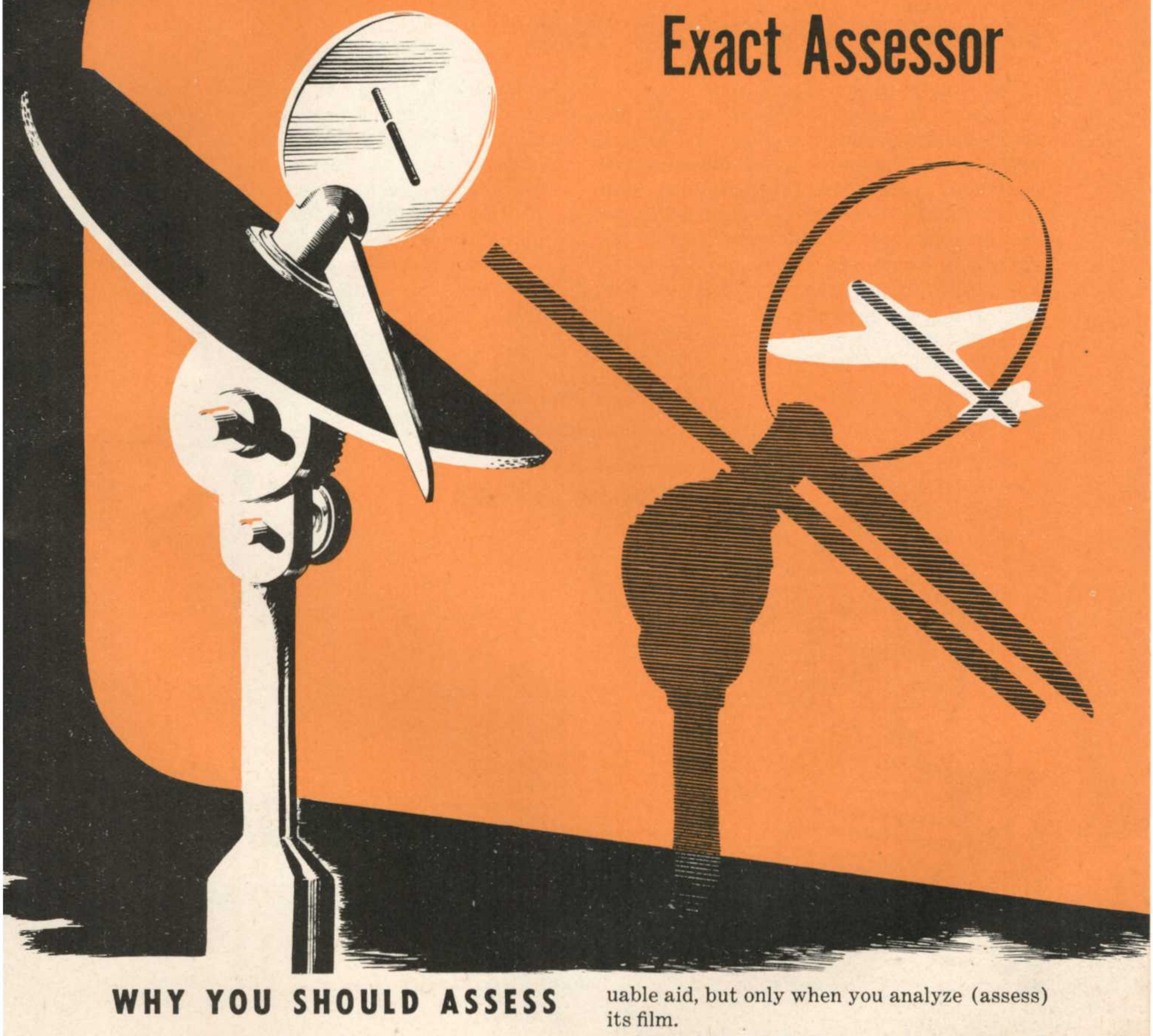
Approach the target in level flight and release the bomb when the depressed sight's pipper touches the base of the target. When using this depressed bombsight (sec. 6) the approach altitude depends on the approach speed.

Sighting allowance tables for various airplanes, approach speeds, and altitudes are listed in AAF Manual No. 52, "Fighter Bombing at Medium and Low Altitudes." This manual was prepared by the AAF Board and published by Training Aids Division, October, 1944. Study these tables until you have memorized the approach speeds and altitudes that get results with your particular sighting conditions.



SECTION 3

Assessing with the W-2 Exact Assessor



WHY YOU SHOULD ASSESS

The A-N gun camera is a gunnery, rocket-firing, and dive bombing instructor and recorder. Its film provides an exact record of your performance and ability. It is an invaluable aid, but only when you analyze (assess) its film.

Assessing aerial gunnery and ground attack film enables you to determine errors in firing range, angle off, alignment, deflection or wind allowance, slant range, and dive angle. You can correct your gunnery technique and make

allowances for the personal equation that is always present in combat flying. Assessing also indicates modifications for future firing and for tactical use of the assessed firing method.

The assessor correctly analyzes film only if:

1. The sighter burst is clearly defined.
2. You fly the airplane smoothly and within allowable G's. Slips, skids, and G's cannot be assessed.

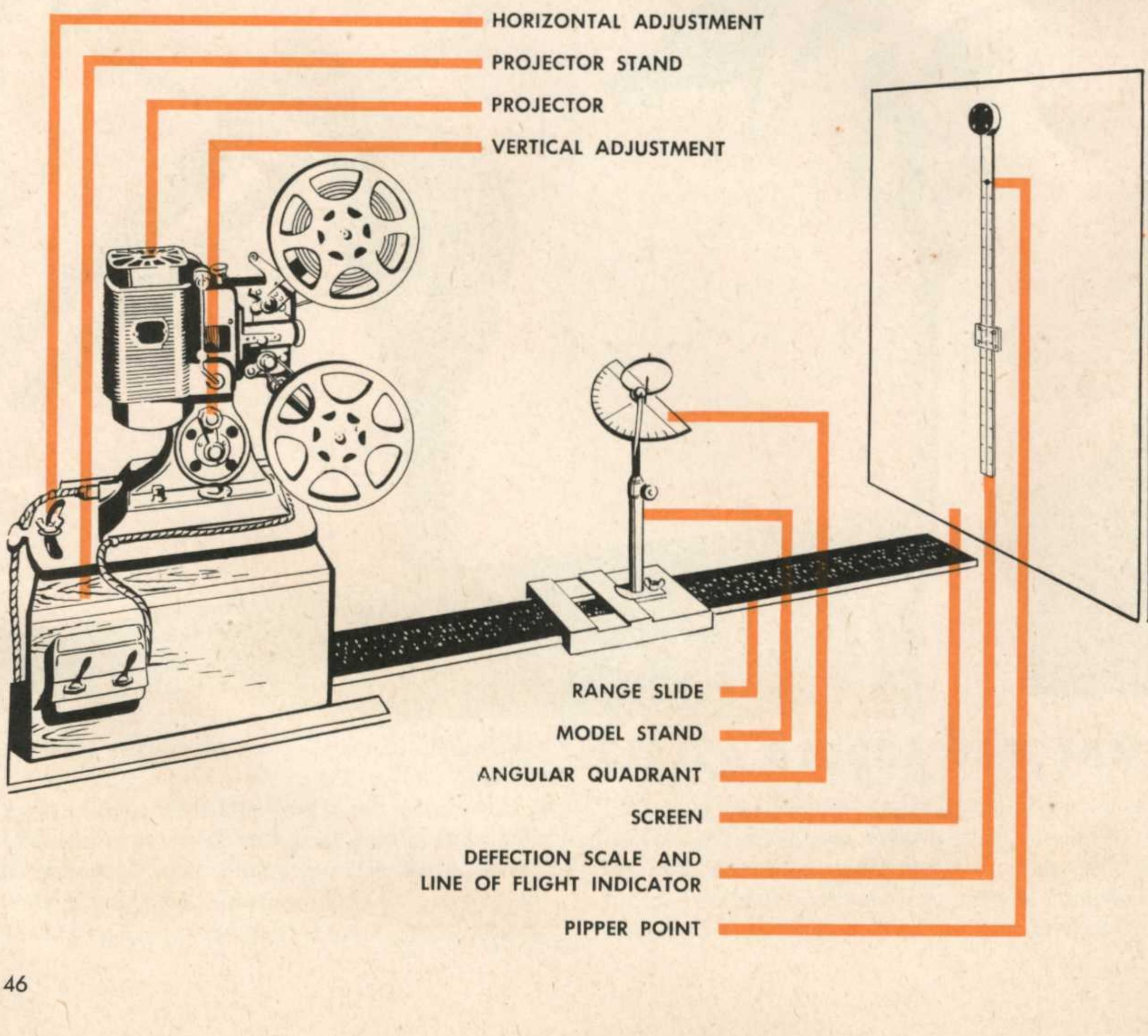
ASSESSING AIR TO AIR FILM

The general theory of assessing:

Project the individual frames as still pictures on a screen and determine the range and angle off of the target—the deflection and alignment you applied. Then, consult a table to find whether the deflection applied was correct for that angle off and target speed. If the deflection, range, and alignment were good, and if the airplane was not slipping or skidding, you flew a good pass.

To find the range and angle off, project a shadow of a model target on the screen and adjust the model so its shadow has the same proportions as the target. Read the model's angle off and range from the scales on which it is mounted. They equal the picture's angle off and range.

Use the following assessing equipment and methods. Your equipment may be slightly different, but these methods are applicable.



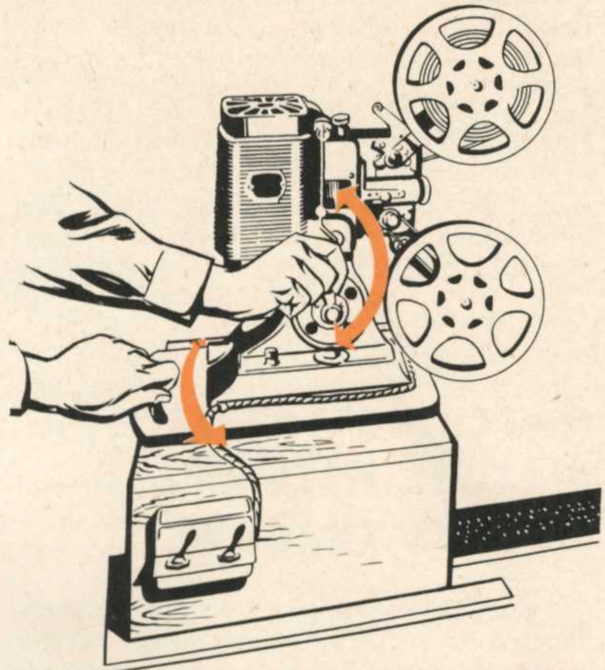
PROJECTOR

The projector is mounted on a stand that pivots around a point 18 in. under the center of the lens. The projector lens should be 15 mm. focal length.

If the camera had a 3 in. lens, the resulting pictures cover a vertical angular field of 98 mils. Place the projector lens about 44 in. from the screen so each five mils cover one inch on the screen or a total of 19.6 in.

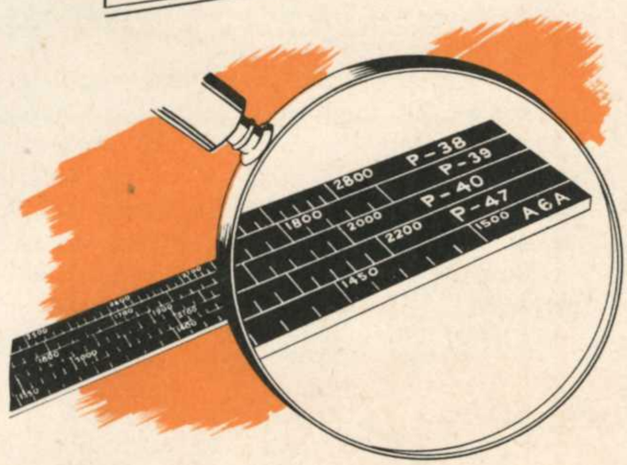
A 35 mm. camera lens covers an angular field of 214 mils. Place the projector lens about 47 in. from the screen so each ten mils cover one inch on the screen, or a total of 21.4 in.

If the picture includes a ring and pipper, adjust the projector so the pipper is on the screen's pivot point. Wing camera pictures do not include the ring and pipper, but you can recognize the sighter burst object and center it on the screen's pivot point.



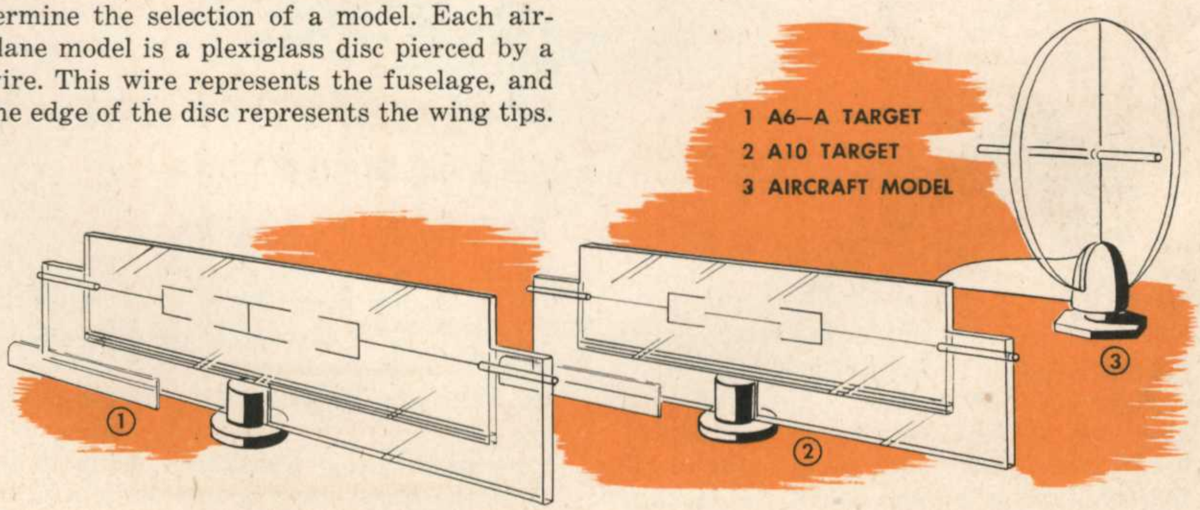
RANGE BOARD

Select the range scale corresponding to the target. This board pivots under the center of the projector lens, permitting lateral movement of the model without changing the shadow's angle off.

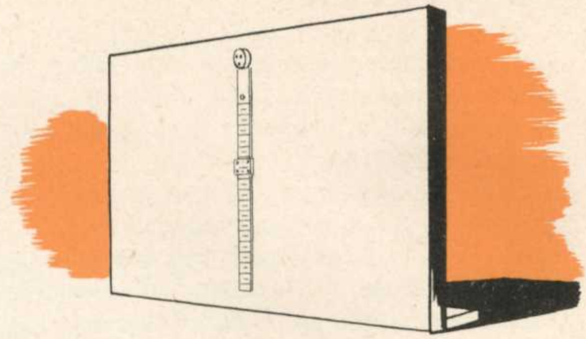


MODELS

The target and the camera lens size determine the selection of a model. Each airplane model is a plexiglass disc pierced by a wire. This wire represents the fuselage, and the edge of the disc represents the wing tips.



SCREEN



The screen has a swinging ruler calibrated in mils pivoting from high center ($22\frac{1}{2}$ in. from the bottom). This rule is used to check alignment and to measure the deflection allowance from the aiming point to the target. The most satisfactory screens are made of non-translucent material such as bristol board.

MATCHING THE TARGET PICTURE WITH THE MODEL'S SHADOW

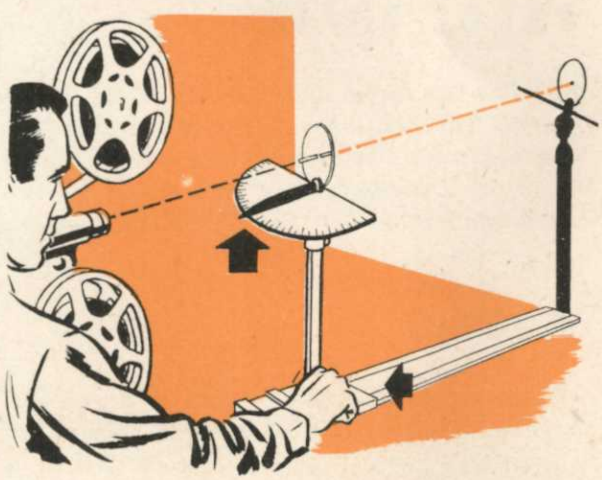
Adjust the model so its shadow is superimposed exactly on the picture. Then read the shadow's angle off and range, thereby getting the target's angle off and range.

First, run the model stand backward or forward on the range board until its shadow is approximately the same size as the projected target. Tilt the quadrant of the model stand so the shadow of the fuselage wire is parallel to the apparent flight path of the target. Now the model is in the same attitude as the target.

Next, zero the model so it will give accurate readings for this particular picture:

Place the model pointer on zero and, after loosening the base thumb screw, rotate the entire model stand until the shadow of the fuselage wire is a small dot. If the fuselage shadow still retains some length, rotate the stand until it is parallel to the quadrant shadow. Then tighten the thumb screw and rotate the quadrant pointer until the fuselage shadow becomes a dot. Leave the pointer in this position and rotate the quadrant to bring the zero line under the pointer. Changing the quadrant tilt 20° or 30° necessitates further zeroing.

The model is now zeroed and ready for the assessment.



SUPERIMPOSING THE SHADOW ON THE TARGET PICTURE

The shadow cast by the plexiglass circle subtends the wingspan. The shadow of the wire subtends the fuselage. The short end of the wire is the airplane nose—the long end is the tail.

Swing the range board back and forth and move the model stand up and down until the

shadow is over the target picture. Tilt the model head for attitude; move the model's stand back and forth on the range board for size; turn the model for angle off.

Tilt the model until the fuselage shadow is along the target's actual line of flight. Then rotate until the outline of the disc touches the wingtips. At the same time, move the entire model stand back and forth on the range board until the wire-fuselage shadow is exactly the length of the target fuselage. It may be necessary to rotate the model slightly.

NOTE: Use three points on the target for superimposing. Any of the following combinations is satisfactory: two wingtips and tail; two wingtips and nose; tail, nose, and either wingtip. If these are not visible, use the center of the wingroot which corresponds to the intersection of fuselage wire and disc. However, this is not as satisfactory as the other choices.

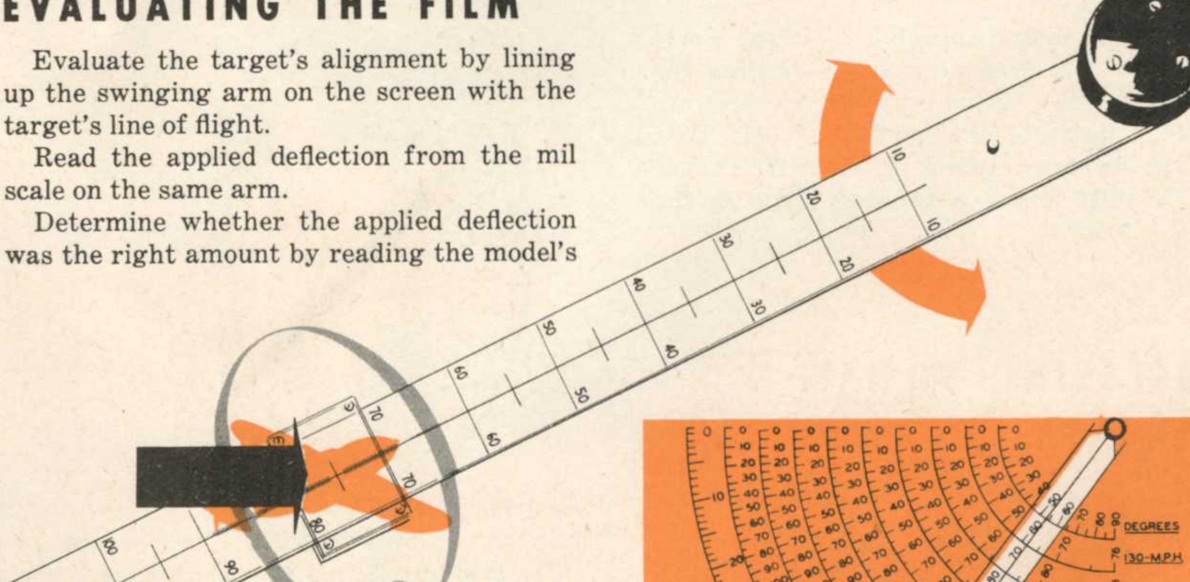
Alterations of any adjustment usually necessitate changes in other adjustments. Thus the problem of superimposing the picture becomes not one of making a series of adjustments in a given sequence, but one of making several simultaneous adjustments. For this reason, it is difficult to outline an exact procedure.

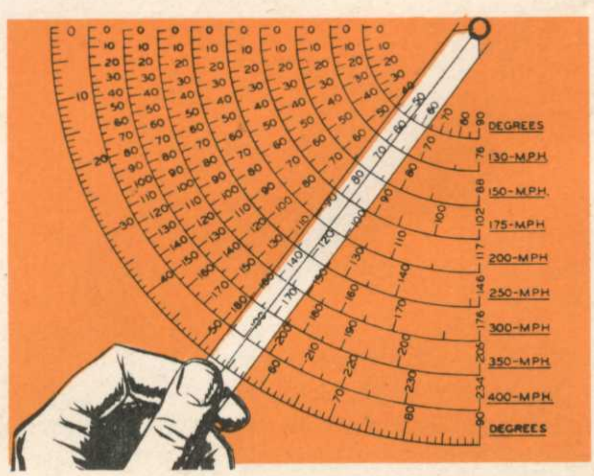
EVALUATING THE FILM

Evaluate the target's alignment by lining up the swinging arm on the screen with the target's line of flight.

Read the applied deflection from the mil scale on the same arm.

Determine whether the applied deflection was the right amount by reading the model's angle off and range and then consulting the deflection scale (a separate unit). This scale gives the mil lead necessary at various target speeds and angles off.





VARIATIONS IN ASSESSING PROCEDURE

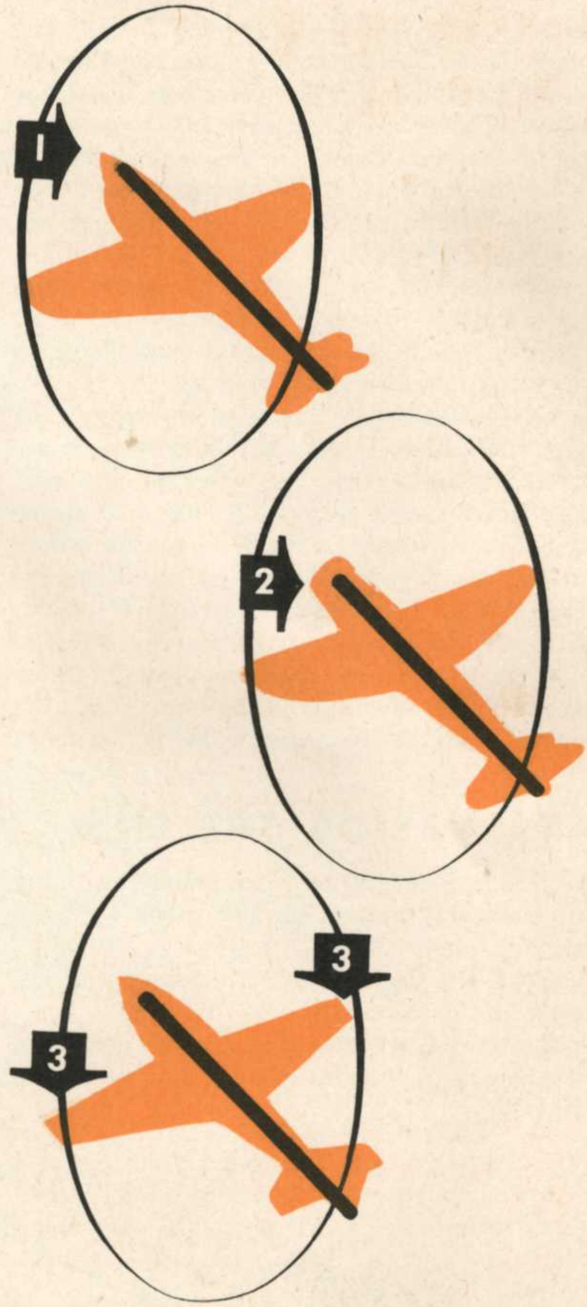
Assessing errors can result because of the design peculiarities of particular targets. Modify assessment procedures if the target has the following design characteristics:

1. Exceptionally long nose (P40)—adjust shadow of fuselage wire so it extends to the base of the spinner.

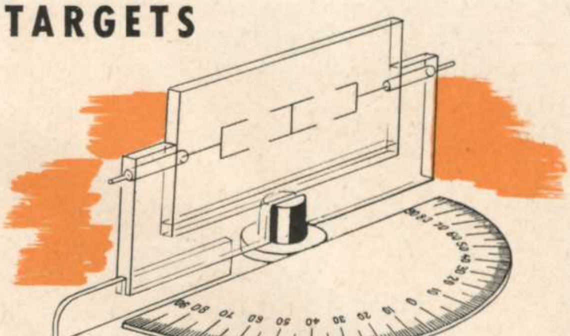
2. Radial engines—at angles off of less than 45°, the true front of the target airplane is obscured by the cowling. Place the front shadow of fuselage wire so it extends to the estimated propeller hub position.

3. Square wingtips—excessive span readings result because they include the diagonal from the leading edge of the near wing to the trailing edge of the far wing. To correct this, span the center of both tip chords, or span the similar edges of both wings.

4. Model interchangeability—if the range at which you fired necessitates moving the model too close to the projector for accurate work, substitute the bomber model. Then divide the range answer by one-half, because the bomber model is twice as large as the fighter model.



ASSESSING TOWED TARGETS



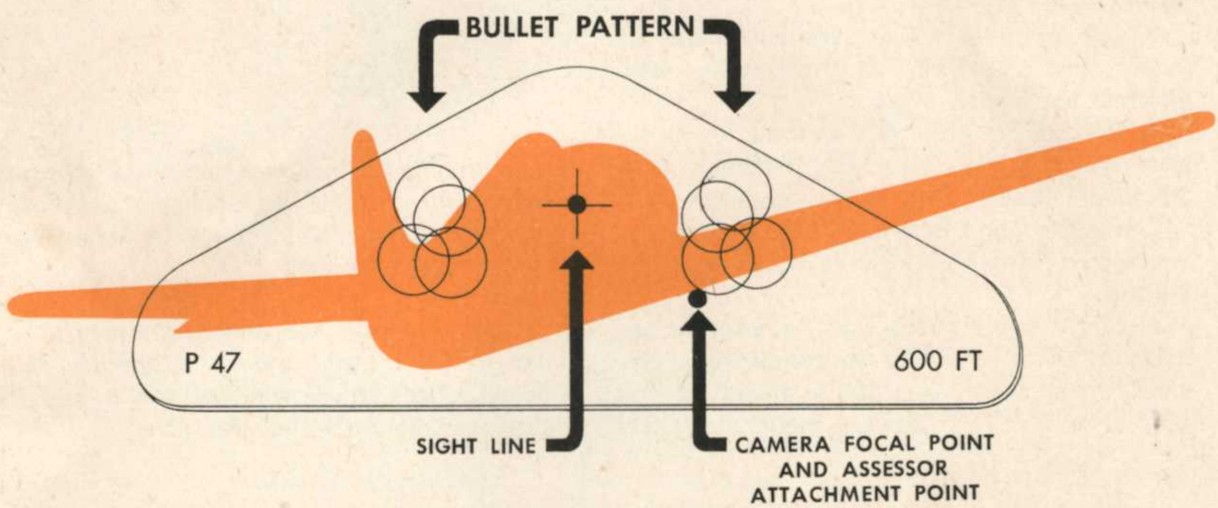
Base the model selection on the target size and camera lens. Zero the model towed target as you did the model airplane target, but make the model shadow as small as possible and tilt it so the shadow's "shoulders" are parallel.

The shadow width gives the range and the shadow length gives the angle off. After establishing the range by sliding the model stand back and forth, rotate the model until the shadow is the same length as the target. If the attack was not on the same horizontal level as the target, turn the model on its longitudinal axis to get the proper angle. Read the range, angle off, and alignment the way you did airplane target assessing.

ASSESSING BULLET DISPERSION

Bullets from a fighter's wing guns make different patterns at various ranges. This is caused by gun harmonization and bullet dispersion. The illustrated template gives the bullet groupings from one fighter at a certain range. Select that template corresponding to the assessment conditions. Attach it to the screen's alignment scale by inserting the scale's pin through the template's camera line hole. The template's bottom edge should be parallel to the bottom of the picture frame.

The indicated bullet pattern represents 75% of the bullets.



ASSESSING AIR-TO-GROUND FILM

Assessing air-to-ground film requires a knowledge of the target's size. This section discusses the assessment of a circular practice target. You can check your dive angle and firing range by matching a circular model's shadow with the target circle. The calibrated model supplies the answer.

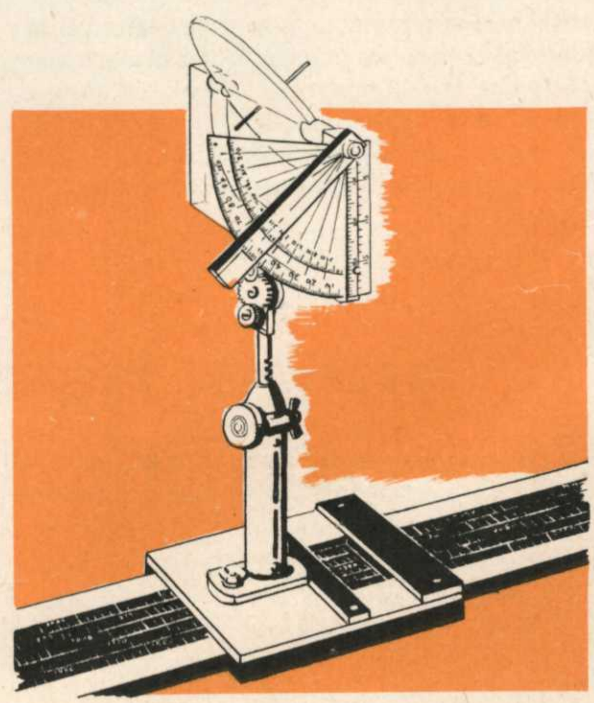
Using the W-2 exact assessor and a model corresponding to the target's size results in dive angle analysis accurate to 0.5° and range analysis accurate to within 10 ft. if:

1. The model ring exactly matches the target ring.

2. The model is zeroed.

3. Three frames are assessed to get an average result.

If such an exact analysis is not necessary, one assessed frame gives understandable answers.



MATCHING THE MODEL AND TARGET

1. Do not assess the first four frames because the camera had not yet reached a uniform speed. Assessing these first frames would result in velocity or acceleration errors.

2. Select a model circle corresponding to the target circle.

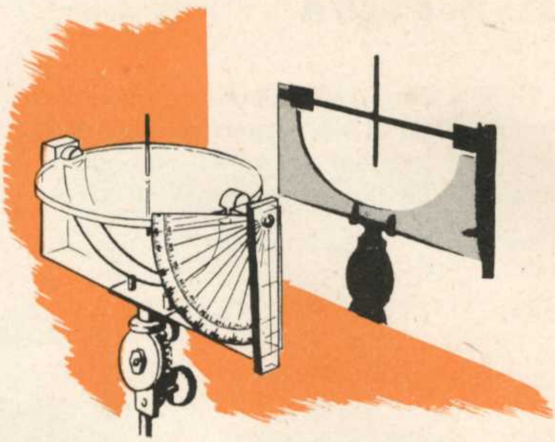
3. Move the model along the range board until the model's horizontal ends coincide with those of the target.

4. Use the model's gear arrangement to tilt it until the axes are aligned. If necessary, raise or lower the model.

5. Correct for inherent assessor error by zeroing the model. Move the indicator until the model shadow is as thin as possible.

Leave the model in this position. Rotate the protractor to bring the zero line under the pointer.

6. Slight adjustments may be necessary in all manipulations: along the range scale, vertical height, inclination of the model; or you may even have to rotate the model stand. Do this by loosening the set screw at the base of the stand.



7. Incline the assessor head with the dive angle indicator until the shadow of the model's circle exactly coincides with the target circle on the screen.

You now have the dive angle answer and can get the range answer from the range board. Check to see whether you were at the proper range in the desired dive.

ASSESSING FOR ACCELERATION AND AVERAGE VELOCITY IN THE DIVE

1. Turn the projector by hand the number of frames necessary to indicate a desired time interval for the same pass. If the camera was operating at 64 frames per second, 32 frames indicate one-half second; 16 frames, one-quarter second, etc. These figures are doubled if the camera was operating at 32 frames per second.

2. Assess the new frame. If the dive angle changes, there was a pilot error. The difference between this range figure and the previous range is the distance the airplane traveled in a given time interval. Get the average dive velocity by the formula $S = vt$.

Get the dive acceleration figure by the formula $S = V_0t + \frac{1}{2} At^2$.

GRAPHICAL ASSESSMENT ANALYSIS

Assess the first frame of a pass and every 8th or 16th frame. Eight assessments per pass are necessary. Assess and record:

1. frame No.
2. angle off
3. lead in mils
4. range in ft.
5. line error in mils (plus for high, minus for low)

FILM ASSESSMENT REPORT

PILOT: JONES SQDN: 1 FLT: B

AIRPLANE: #P84Y TYPE: P51D DATE FLOWN: 10 JAN.

FIGHTER SPEED: 250 TARGET: B26

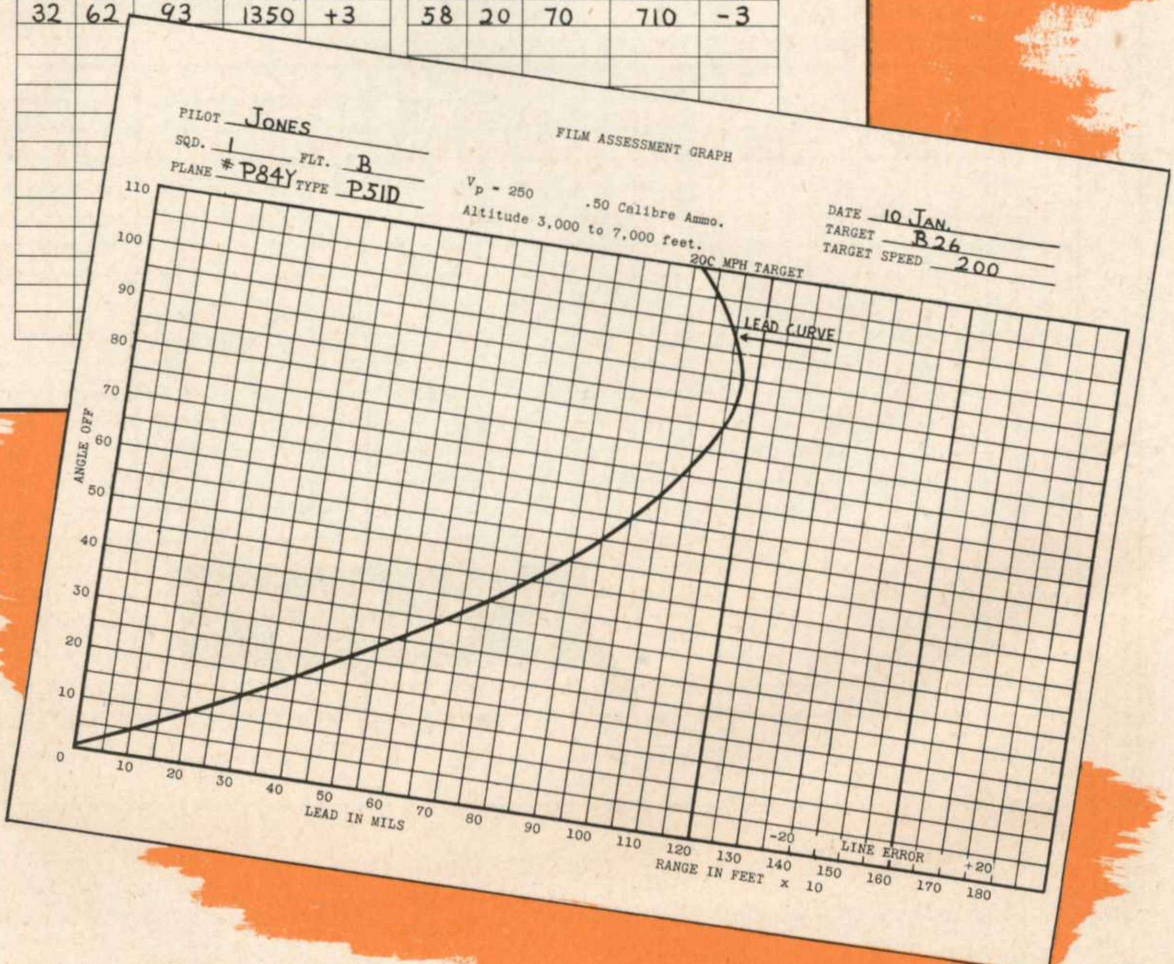
EXERCISE: #7 ALTITUDE: 7000

ATTACK: #1 and #5 SPEED: 200

ASSESSED BY: JONES DATE ASSESSED: 11 JAN.

INSTRUCTOR'S COMMENT OR GRADE	FILM QUALITY
✓	Good

Frame No.	Angle Off Deg.	Lead Mils	Range Feet	Line Error Mils	Frame No.	Angle Off Deg.	Lead Mils	Range Feet	Line Error Mils
		ATTACK #1					ATTACK #5		
4	69	107	1700	+10	4	40	85	1300	+1
8	68	105	1650	+8	12	37	83	1200	-5
12	67	103	1600	+6	20	34	80	1100	-4
16	66	101	1550	0	28	31	78	1020	-10
20	65	99	1500	+3	36	28	77	930	+5
24	64	97	1450	+2	42	25	75	850	+2
28	63	95	1400	+1	50	23	73	780	0
32	62	93	1350	+3	58	20	70	710	-3

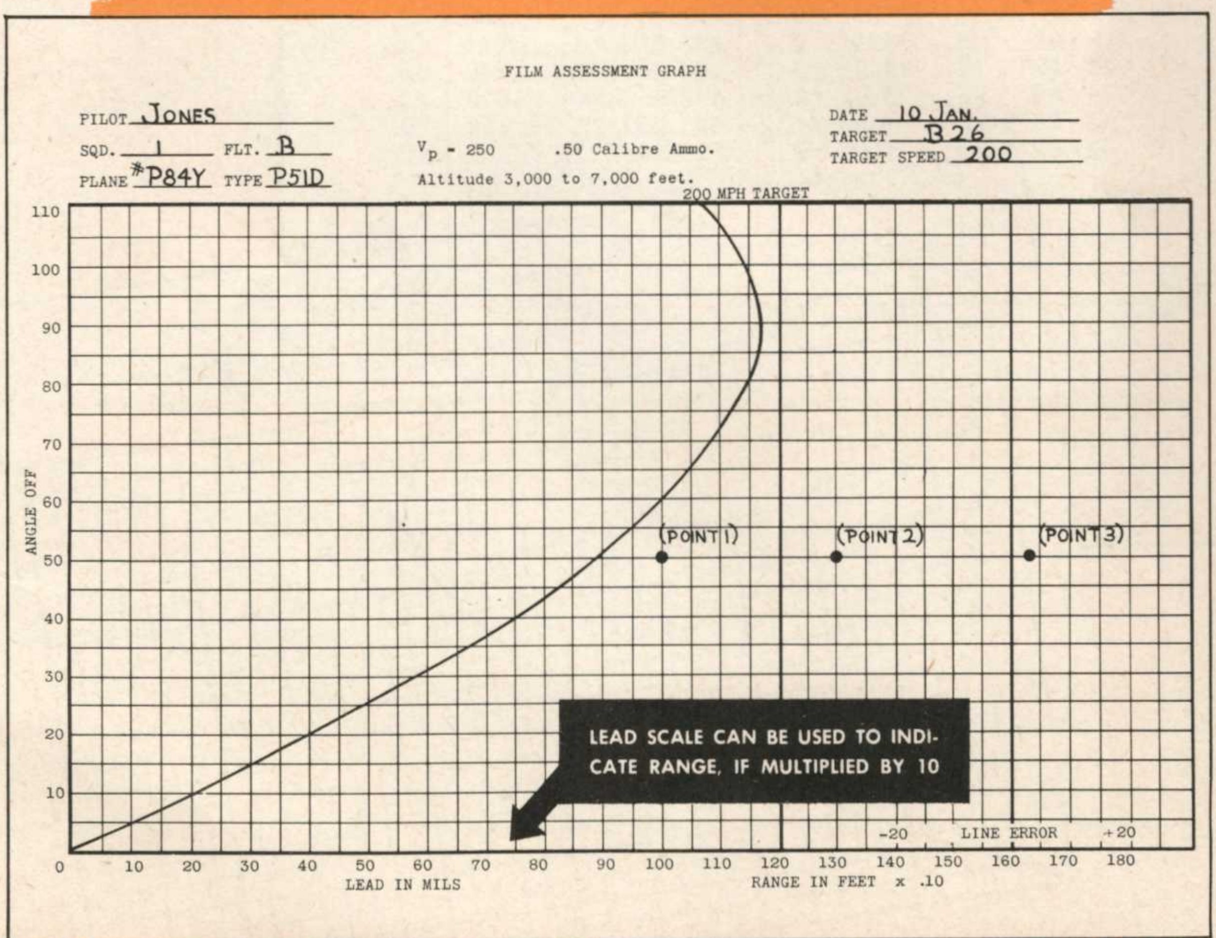


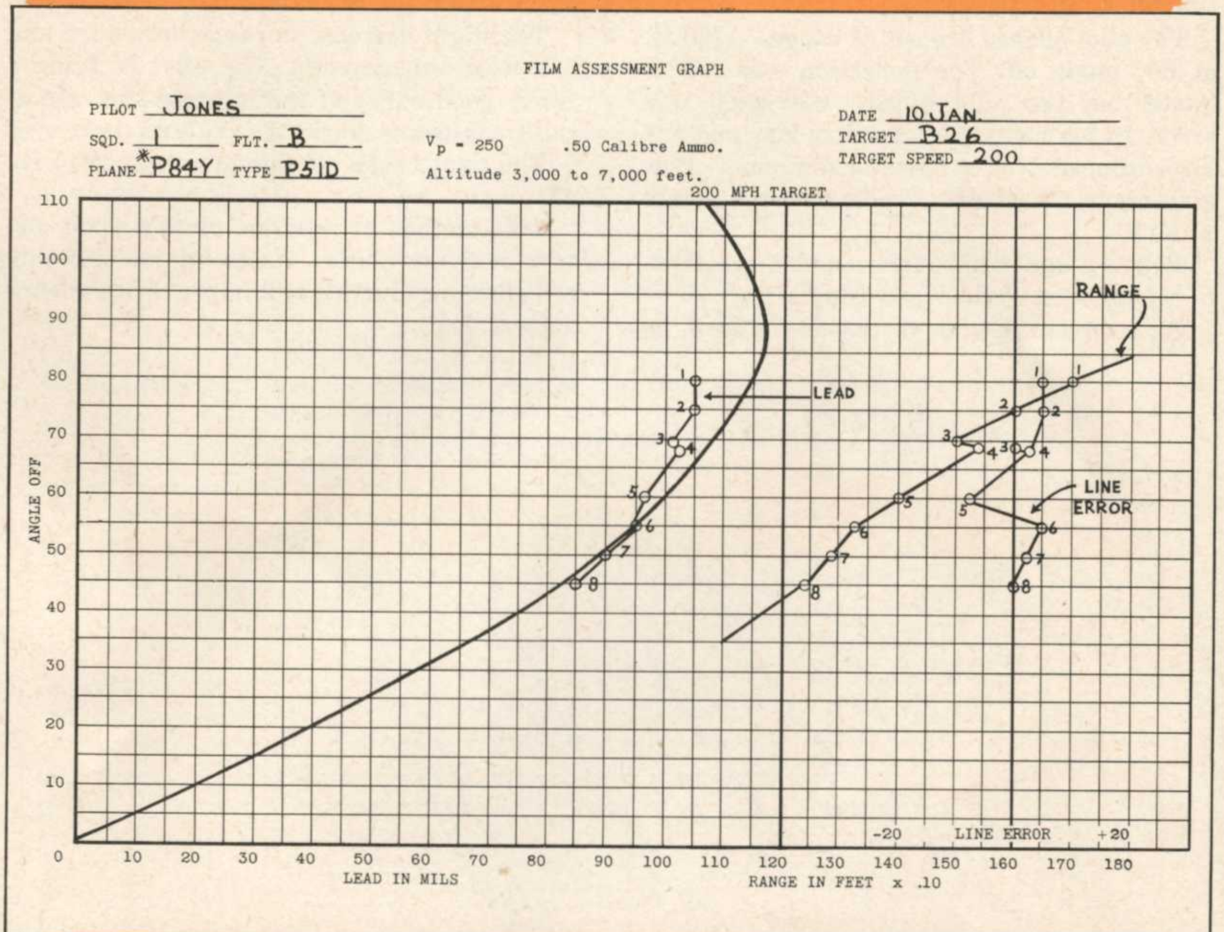
PLOTTING THE GRAPH

Select a graph having a lead curve plotted for the target speed of this assessment. Angle off is on the left side reading up. Lead and range are on the bottom of the graph, increasing from left to right. The numbers on the bottom of the graph are mils and are used for lead. Multiply by 10 and these numbers become range in feet. The line error chart is on the right side of the graph: the left side records low (–) shooting, the right side high (+) shooting.

Plot the assessment data by matching the target's angle off on the left side with the lead allowance on the bottom. Record the alignment error along the chart opposite the same angle off. Do this for each assessment.

Suppose the first assessment reads 50° angle off, 100 mils lead, 1300 ft. range, and +3 alignment error. Move up the left side of the graph to 50° and then right until you cross the 100 mil mark. Make a pencil dot (point No. 1). Continue along the same line to the right and make another mark where the 50° line and 1300 ft. line cross (point No. 2). Place another mark where the 50° line and the +3 mil line cross (point No. 3).





COMPLETED GRAPH

ANALYSIS OF THE GRAPH

The accuracy and quality of your flying can be analyzed from the graph by comparing the actual lead curve with the ideal lead curve. If the lead curve is to the left of the ideal lead curve, you were under-leading. If the curve over-leads and then cuts across the ideal curve, a snap shot is indicated. If the curve under-leads and then over-leads, you realized the incorrect deflection allowance and applied more deflection. This is usually reflected on the alignment graph and indicates you walked rudder to increase lead.

The range curve shows when you fired in range as well as poor assessing.

Find how many feet the airplane moved toward the target between assessments (32 frames per second). The range curve moves forward evenly at the high angles off and slows down on the smaller angles off. If it doesn't, there is an assessing error.

The line error can show smooth flying even though you were shooting high or low. If the line error crosses from one side to the other,

rough flying and skidding are indicated.

An analysis of the completed graph reveals the following information:

The pilot opened fire out of range—1700 ft. at 80° angle off. The deflection was inadequate, but the pilot quickly corrected this error. In his haste, he kicked rudder and the nose dropped. Notice how the alignment error goes from +3 mils to -7 mils between points 4 and 5.

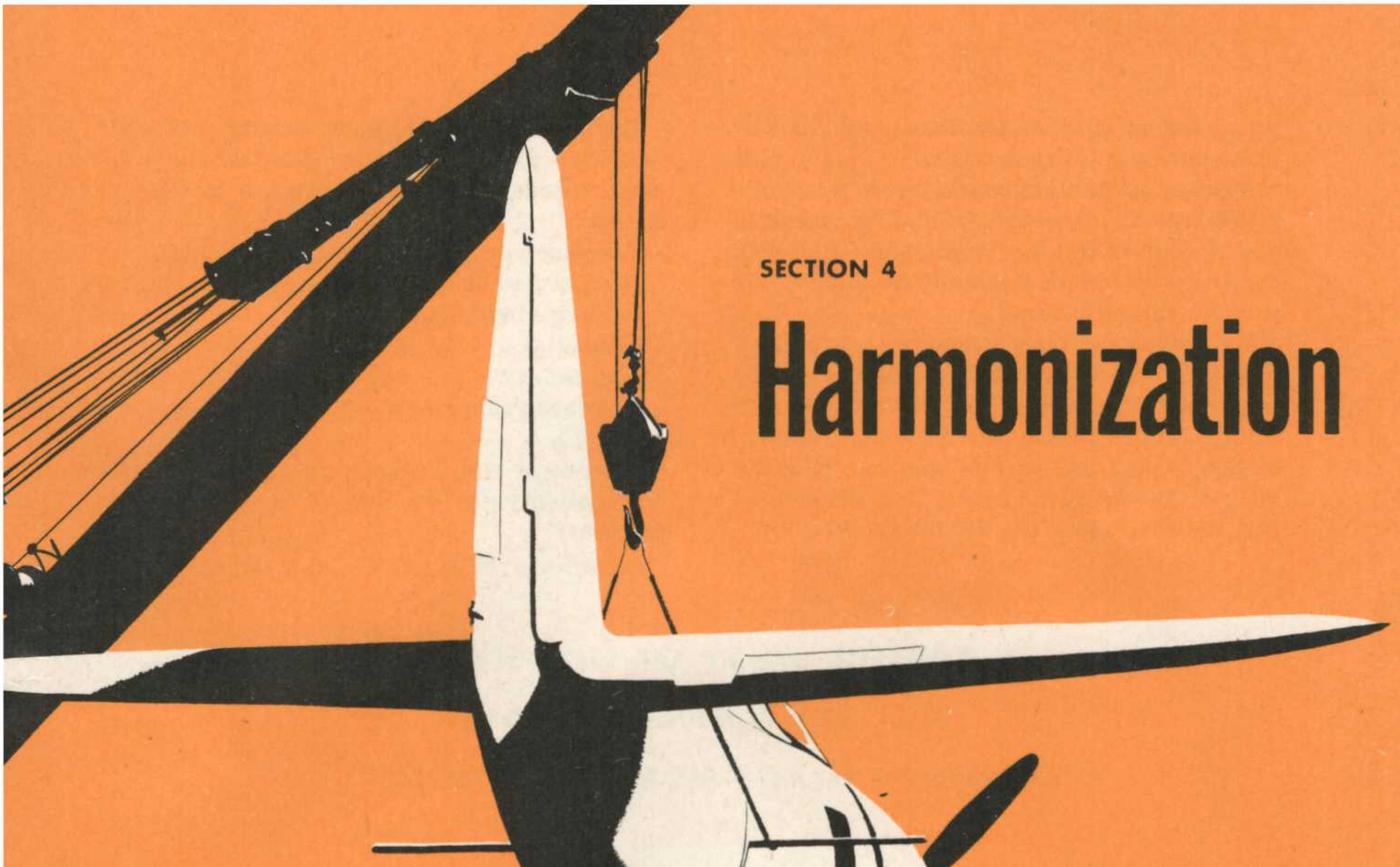
Points 3 and 4 indicate a sudden cessation of closure—an obvious assessing error.

As soon as the pilot increased the lead, he noticed he was firing low and made a correction. If he had not corrected here, the lead curve would fall off.

The slight decrease in range between 5 and 8 is assessed correctly. The pilot is flying a fairly good curve of pursuit and the rate of closure is decreasing as the angle off decreases.

The pilot broke off this attack at 1240 ft., 45°.

This method of analysis gives a good picture of flying ability. Assessing and plotting ten missions like this will improve proficiency a great deal.



SECTION 4

Harmonization

INTRODUCTION

In the early part of this war our pilots were doing an excellent job with inferior equipment. Their knowledge of fixed aerial gunnery was not as complete as it is now.

Pilots had workable guns, sights, and airplanes, but unfortunately they were not always coordinated into one good fighting weapon. At that time, few people thoroughly understood the complete function of the gunsight, guns, and airplane as a firing platform for the new high-speed aerial warfare. Frequently the sight pointed in one direction, the

guns shot in another direction, and the airplane flew in a third direction.

Fighter pilots did not realize that a single rough landing might throw the guns and sight out of alignment. Even today many pilots do not know how important and how simple it is to check this alignment.

Keeping a fighter airplane on operational status is more difficult today than during the early part of the war. This is because new equipment has been added. Although **harmonization** is only one part of this job, it is the most important part because **it is the process that actually gives the fighter its sting.**

Harmonization technique has been refined to a high degree. **These are the factors you must consider in attaining complete harmonization:**

Airplane
Airspeed and loading
Effective bullet pattern
Gunsight
Gun camera
Forward firing rocket

Your crew will do the work, **but it is your responsibility to see that it is done when necessary.**

A CAREFUL STUDY OF THIS SECTION WILL PAY DIVIDENDS—WHEN DIVIDENDS MEANS MORE THAN MONEY!

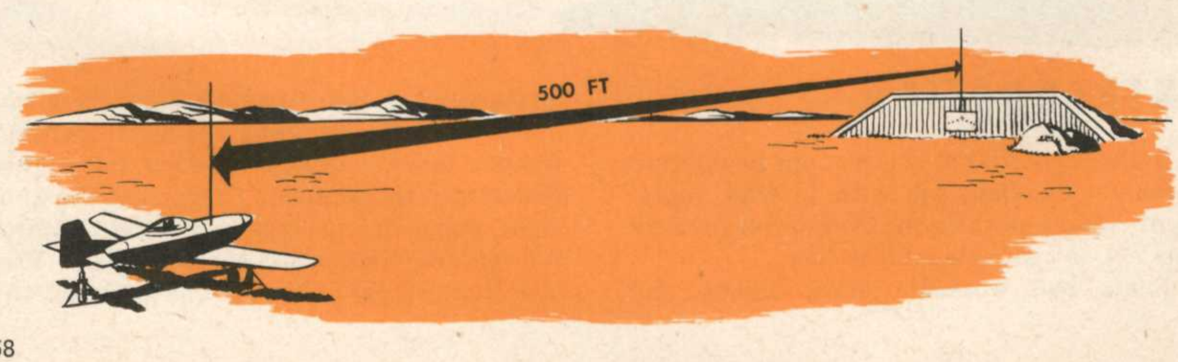
HARMONIZATION PROCEDURE—FOR AIRPLANE, SIGHTS, GUNS AND CAMERA

THE 500 FT. BORESIGHT AND FIRE-IN TARGET METHOD

1. Select a level strip of ground a little more than 500 ft. long. An actual boresight range of 500 ft. is used in this discussion for purposes of illustration. Firing-in ranges can be anywhere from 500 ft. to 1000 ft., but to pattern-harmonize effectively the range should be about 500 ft. At greater ranges the boresight points tend to converge into one point and the pattern cannot be determined accurately.

If you use this distance, harmonization charts with other basic distances must be corrected properly. This should be done only by competent personnel.

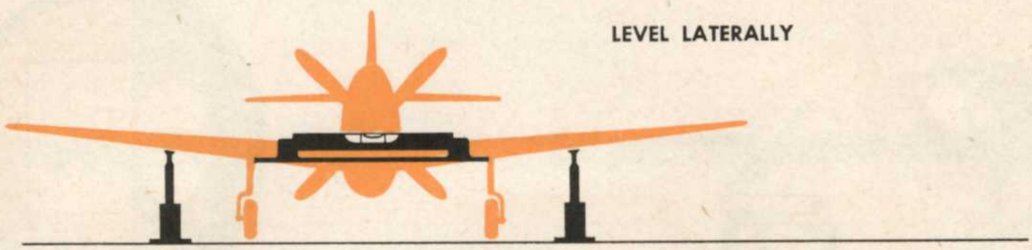
Measure the 500 ft. distance from the target to the average of the gun-trunnion bolts. Select a safe direction of fire. If necessary, place the target in front of a standard gun firing butt. Include a safety station near the target for a target scorer.

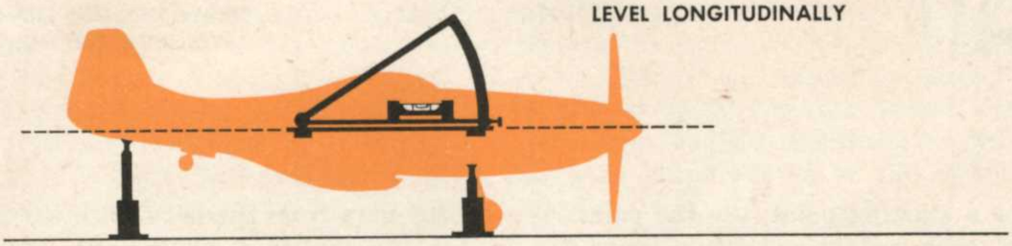


2. Level the airplane on both axes and fix it firmly by means of weights and jacks. Level the fuselage by placing a level on the leveling lugs. If you first level the airplane laterally, it will be easier to adjust the longitudinal leveling.

You can level airplanes with nosewheels longitudinally with jacks or by setting the nosewheel down an incline.

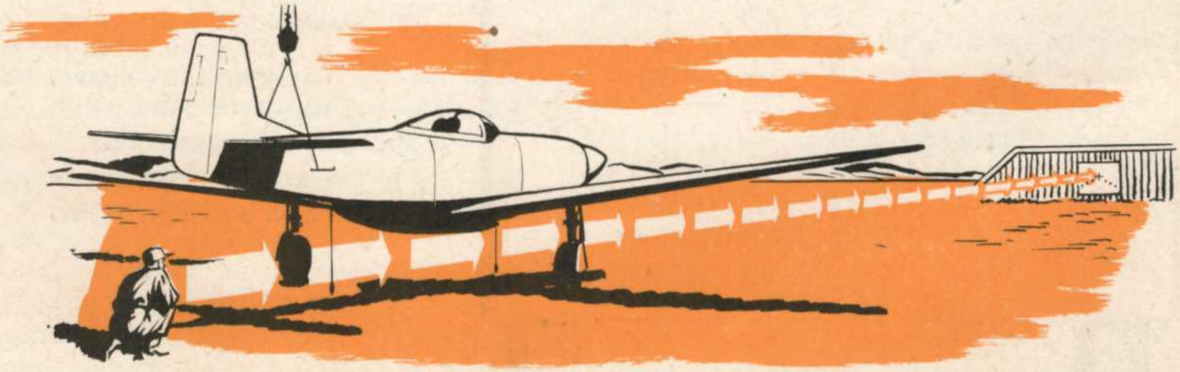
When you jack up the tail on nosewheel type aircraft, make sure that the nosewheel strut is not compressed beyond its maximum. It may be necessary to release the strut somewhat, or to run the nosewheel down an incline.





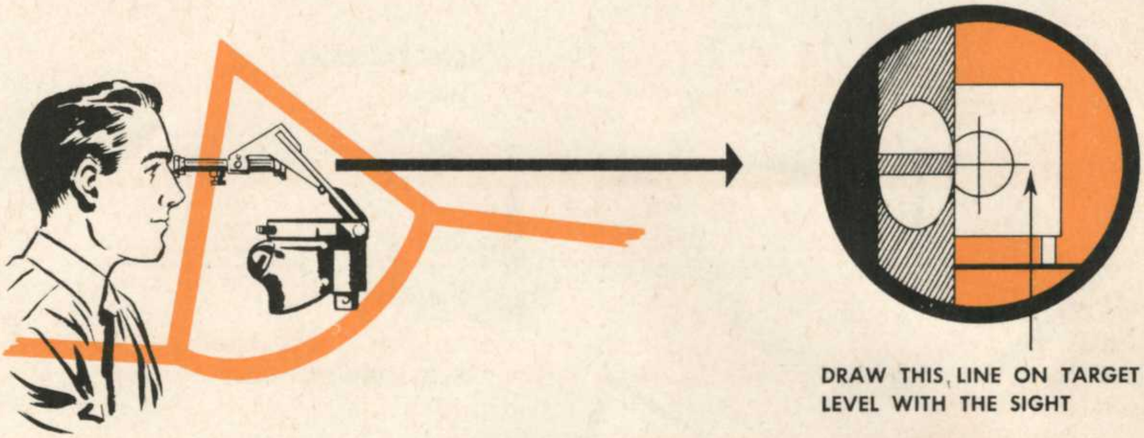
3. Line Up the Airplane Laterally. Draw a vertical line on the target in line with the center of the airplane. You can move a previously prepared target laterally until it is lined up with the bob weights on the airplane. Do this by attaching plumb bobs to the red circled plumb bob nut plates and sighting along the plumb bob cords. If the airplane has a nosewheel, the plumb bobs will not be on the center line of the airplane. You must make proper allowance for this. Keep the eye sufficiently behind the first bob line so that both bobs are clearly visible.

If there is a strong wind, let the bobs hang in cans of water or oil. This dampens the vibration.

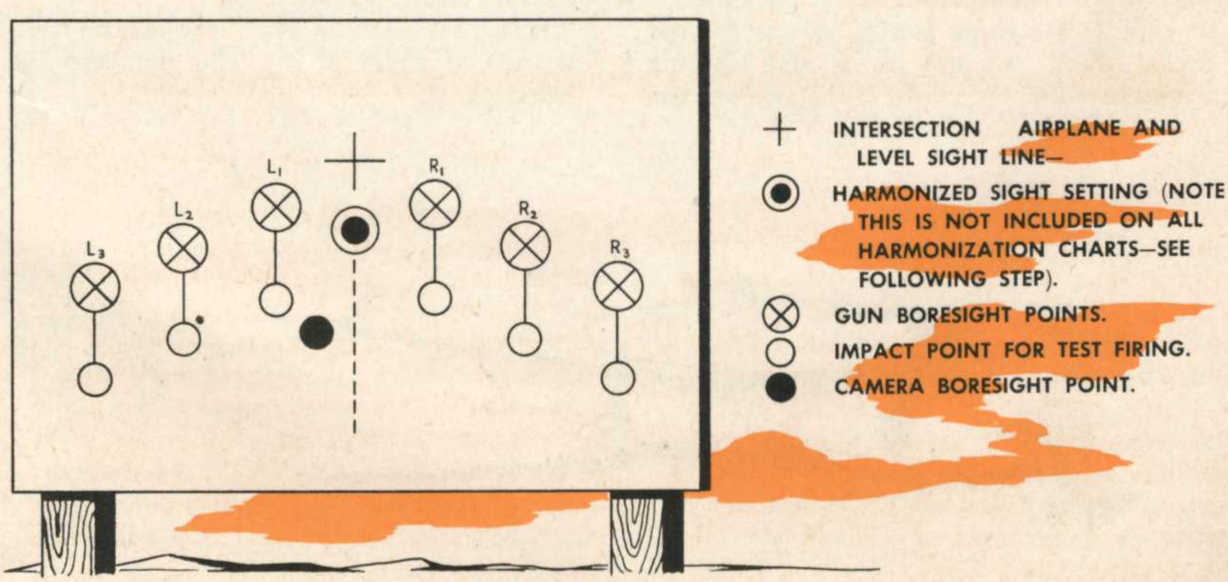


4. Place a sight-line level indicator on the gunsight glass reflector. Then, without turning on reticle light, project a level point from the sight to the target. Using this level point as a reference (you can see it through the sight as shown in the illustration), draw a horizontal line on the target through the vertical line you found in step 3. A line from the sight to the target at this setting is parallel to the fuselage reference line, or level lugs.

With a solid black bullseye, or previously prepared target, move the target up or down until the bullseye is centered with the crosshair and with the bubble in the sight-line level.

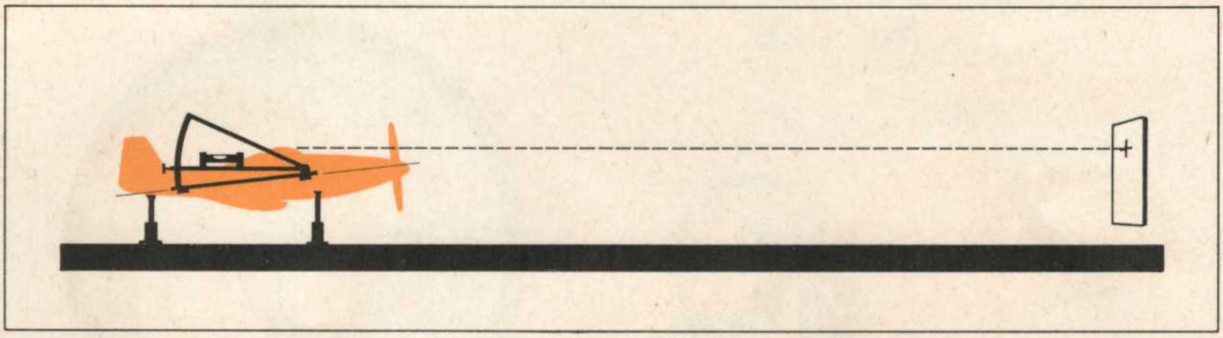


5. For a starting point, use the point located on the boresight and fire-in board (in step 4), which is the intersection of the horizontal and vertical lines on the target. Mark off, to the proper dimensions, the points where the fixed sight-line and guns are to be aimed. Copy data from the harmonization diagrams for the proper airplane type. Include the camera boresight point. For the 750 to 1000 ft. fire-in ranges, these points tend to converge and form a bullseye. Therefore, it is preferable to pattern-harmonize at a 500-ft. distance.



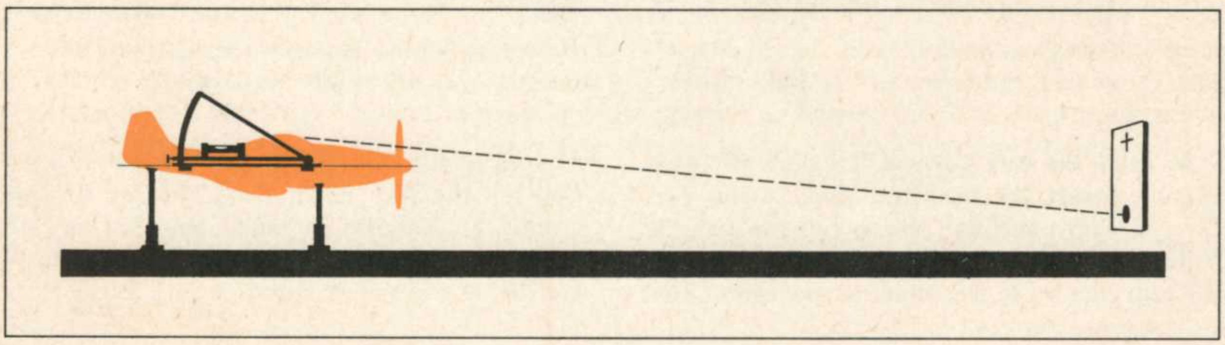
6. Align the Gunsight. This step can be done in two ways, depending on the type of harmonization chart used. Both methods are correct, if you know and follow properly each method.

The first method uses harmonization charts that do **not** include the angle of attack. The second method uses harmonization charts that **do** include the angle of attack.



Method No. 1:

Consult the angle of attack chart for the airplane being harmonized. Select a desired airspeed and determine from this chart the number of mils, nose up or down, that the airplane flies at this speed. Readjust the quadrant level on the airplane level lugs to mil reading as directed by the chart. With this setting on the quadrant, raise or lower the tail as required to give a level reading. This incorporates the proper angle of attack to the airplane. Remove the sight-line level indicator and turn on the sight. Then readjust the pipper to the cross mark on the boresight target. The gunsight is now aligned in azimuth and zenith for the basic harmonization at the selected airspeed.



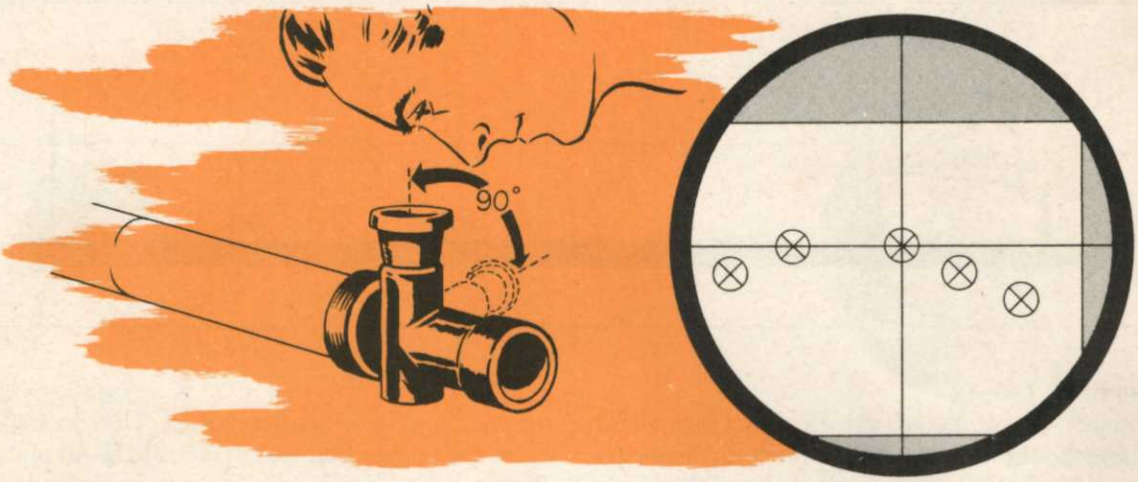
Method No. 2:

Remove the sight-line level indicator from the gunsight. Do not change the airplane's attitude, but keep it leveled as originally set. Readjust the gunsight pipper from the cross point on the boresight target to the harmonized sight setting on the boresight diagram. This readjustment of the gunsight to the new sight setting automatically incorporates the proper angle of attack. It isn't necessary to consult the angle of attack chart or to re-level the airplane. The gunsight is now aligned in azimuth and zenith for a basic harmonization.

Regardless of which method you use, eliminate any double image or **parallax** before locking the sight in position. If a double image or parallax appears, install a new sight. If you cannot get a new sight, obtain a new reflector glass that does not give a double image.

To eliminate parallax, re-focus the sight lens system. Focus the system for infinity. Sights like the N-9 must usually be replaced completely because they are pressurized and sealed. (See Sec. 6, "Sights".)

7. Align the Guns. Use the boresight tool to align the guns so that they point at their respective targets. Do not handle the tool while sighting. Rotate the tool through at least 90°. If the crosshairs move off the boresight point, the tool is bent or out of line.



8. Check the Boresight. Fire a burst of 10 rounds from each gun individually. The center of the bullet pattern from each gun should fall on the predicted center of impact previously marked on the target. If these points do not coincide, adjust the guns until they do fall on the predicted center of impact marked on the target.

9. Align the Gun Camera. To align the gun camera insert the boresight tool in the gun camera. Sight through the tool to the camera point mark on the target. See the section on the gun camera in this manual. Boresight the camera in the center laterally and about one-quarter the way down from the top of the frame. This allows for more lead during deflection shooting than if the camera were boresighted in the center through both axes.

THE 1000-INCH BORESIGHT TARGET METHOD

Although it is possible to use either the 1000-inch boresight target or the 500 ft. boresight and fire-in targets, the 500 ft. boresight and fire-in method is preferable. It should be used whenever possible because it is more accurate.

The method for the 1000-inch boresight target is exactly the same as the method described in steps 1-9, omitting step 8. The guns are not test fired on a 1000-inch boresight target.

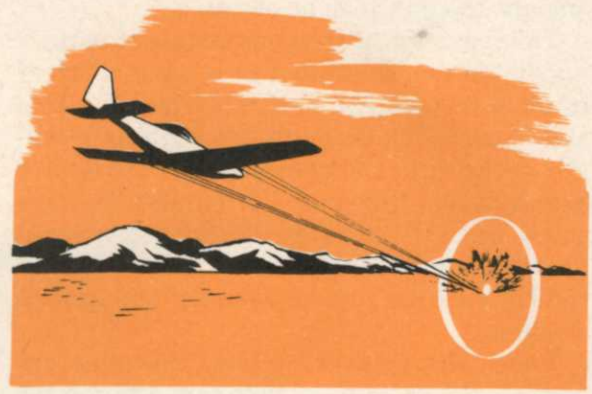
FLIGHT TESTING HARMONIZATION

Your gun harmonization MUST be checked frequently in practice or in combat. And it is the PILOT'S responsibility to do this. The job is YOURS. The armorers and the line crew will help you correct any errors you may find.

To Flight Test Gun Harmonization: Fire a burst at the ground or water to check if the bullets hit where you see the pipper. Make sure the slant range is the same as the harmonization range.

To Flight Test Gunsight Harmonization: Determine the indicated airspeed for which the airplane and sight are harmonized. Turn on your sight. Fly the airplane at the harmonized indicated airspeed and hold level flight on the altimeter so that the airplane is not climbing or diving. The pipper should then be aligned with the horizon. This indicates the airplane's flight line and the sight line are parallel. The air should be fairly smooth when this is done.

If the pip is above or below the horizon when the airplane is flying level at its harmonized speed, then the sight is set for some other airspeed. Determine how many mils above or below the horizon the pipper indicates, and report this to your armament crew. If the pipper is off more than 10 mils, it is recommended that the harmonization be checked.



TYPES OF HARMONIZATION

The practice of converging all guns at some one point along the path of flight or sight line is commonly referred to as **Point Harmonization.** Although it results in a heavy concentration of fire at certain ranges, it produces excessive dispersion at others. The heavy concentrations of fire at selected ranges are undesirable because they produce bullet densities in excess of the lethal density required. This is an inefficient use of available fire power which requires too many refinements in aiming.

For a **superior** fixed gunner, Point Harmonization is probably the best type. For the **average** pilot, a PATTERN TYPE HARMONIZATION is more desirable because it makes up for his deficiency in shooting.

PATTERN HARMONIZATION

The best arrangement of guns is one which produces the largest pattern of a uniform lethal density over the entire effective range.

These harmonizations fix the sight line approximately in the center of the projectile pattern throughout the effective range, when the airplane is flown at the basic harmonization. This relieves you of any need to calculate the projectile drop within the limits of effective range. Maximum effective range for harmonization purposes is considered to be 2000 ft.

Harmonization patterns do not eliminate the necessity for computing the proper **lead.** The subject of lead is covered in the section on Air Firing in this manual.

HARMONIZATION CHARTS

In the back of the manual are typical examples of harmonization charts. They have been test-fired and checked with gun-camera film assessments. They give you an efficient all-around pattern.

These patterns have been used with good results, and have been printed only in limited editions. That is why they are included in this manual. All the charts are for ammunition with a muzzle velocity of approximately 2700 ft./sec. unless otherwise indicated.

NOTE:

SEE HARMONIZATION CHARTS IN THE BACK OF THE MANUAL

GENERAL INFORMATION ON HARMONIZATION

Basic Harmonization is computed for an altitude, airspeed, and aircraft weight which constitute the average conditions of combat firing. In the basic harmonization, it is vitally important to obtain the greatest possible angle of visibility over the nose of the airplane. To do this, the sight line has to be raised to its maximum. This is limited mainly by the amount the guns can be elevated.

This elevation of the guns and sight to their maximum is also limited to a certain extent by other factors that involve the use of rockets and bombs. Furthermore, too high an elevation of the sight and guns will place the fighter on a different type curve of pursuit. In some cases, when the same sight is used for aerial fighting, strafing and bombing, it will limit the fighter's use in dive bombing and ground strafing.

Under the present system, the guns are normally elevated to an optimum position for air-to-air firing, and the sight is harmonized with their effective trajectory curve. This method gives the sight its greatest visibility over the nose.

For rocket-equipped fighters, a lower trajectory curve and sight setting may be desirable. The mil angular trajectory shift, caused by flying at conditions other than those of basic harmonization, is shown on the charts by the Greek symbol μ

Angle of Attack

The angle of attack of fighter airplanes for all speeds and loading conditions should be known as accurately as possible. **This is necessary** when harmonizing an airplane by METHOD NO. 1. **It is not necessary** when using METHOD NO. 2, because the boresight pattern in the second method includes the angle of attack calculations. This is done by adjusting the sight pipper to the harmonized sight position from the original reference point.

The term **angle of attack** is used rather loosely here. It is not the actual aerodynamic angle of attack. It is the angular measurement between the flight path of the airplane at a certain speed and some reference line on the airplane, i.e. **level lugs line, fuselage reference line, or zero thrust line.**

In rocket harmonization, the term **datum line** is used sometimes for the **level lugs line.** The guns are oriented to any one of these reference lines so that they may be at the proper or desired setting relative to the actual flight path of the airplane.

Angle of Attack Data

Angle of attack data can be found in the Technical Orders for each airplane. In some cases they are on charts located in the gun bays or on the ammunition doors. Harmonization data in this manual is based on the best available information on angles of attack. These are the limitations of the data:

Since the wing installation on all airplanes is held to a manufacturer's tolerance of plus or minus ½ degree, these charts are no better than the manufacturer's accuracy.

Under various "G" loadings the angle of attack for the same airspeed varies from the corresponding value for the level flight condition of one "G" loading.

The angle of attack for the same airspeed and "G" loading varies with the different degrees of dive. This is not so important for gun harmonization as it is for rockets and bombs, which are usually launched in a diving attack. The following charts are typical angle of attack vs. airspeed charts for several types of airplanes.

P-51D AIRPLANES

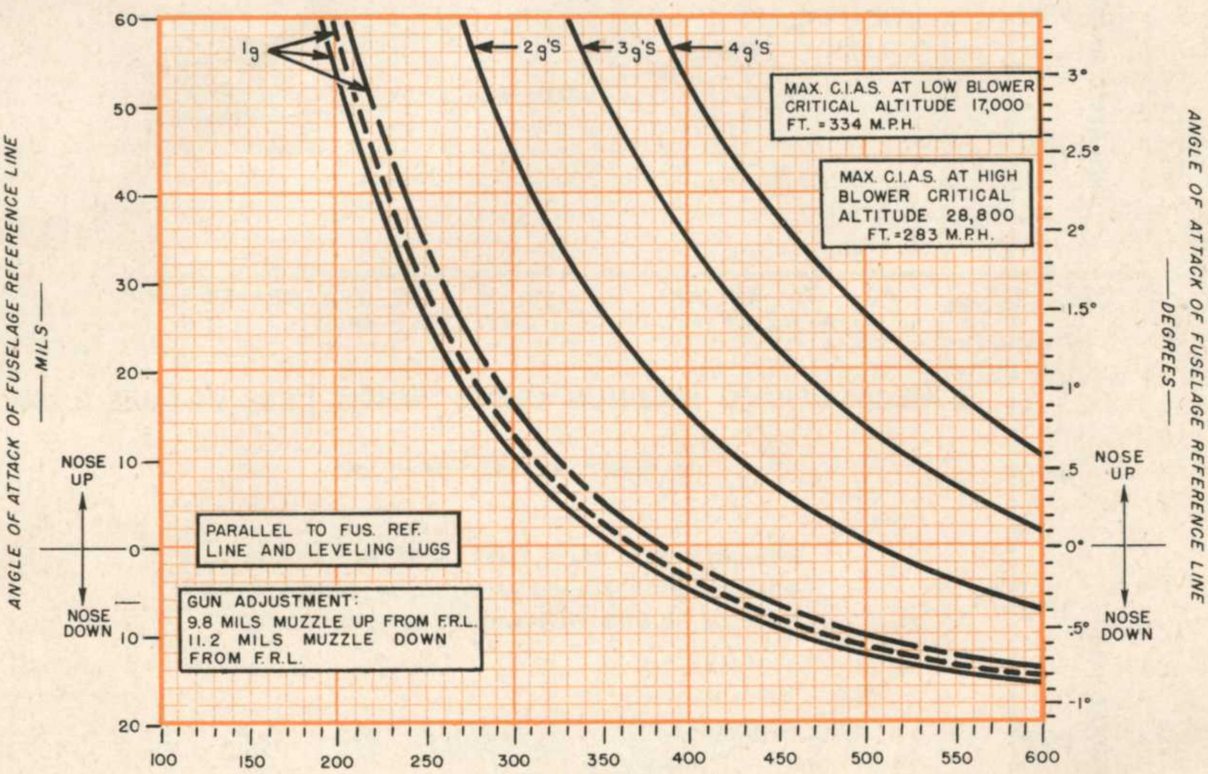
HORIZONTAL DISTANCE FROM ℄ GUN BORE (AT FRONT MOUNT) TO ℄ OF AIRPLANE	INBOARD CENTER OUTBOARD GUN CAMERA	79.123 87.091 95.076 25.561
VERTICAL DISTANCE FROM ℄ GUN BORE (AT FRONT MOUNT) TO ℄ GUN SIGHT REFLECTOR	INBOARD CENTER OUTBOARD GUN CAMERA	* 44.732 * 44.003 * 43.493 * 50.890 * ADD .750 WITH SIGHT IN HIGH POSITION

LEGEND

——— FULL AMMUNITION, LESS 1/2 FUEL, WITHOUT BOMBS (=9065 LBS.) UNDER POSITIVE ACCELERATIONS OF 1g, 2g, 3g, OR 4g'S.

— — — MAXIMUM OVERLOAD GROSS WEIGHT, LESS 1/4 FUEL, WITH BOMBS (=10,358 LBS.) UNDER POSITIVE ACCELERATION OF 1g.

- - - - MAXIMUM OVERLOAD GROSS WEIGHT, LESS 1/4 FUEL, WITHOUT BOMBS (=9354 LBS.) UNDER POSITIVE ACCELERATION OF 1g.

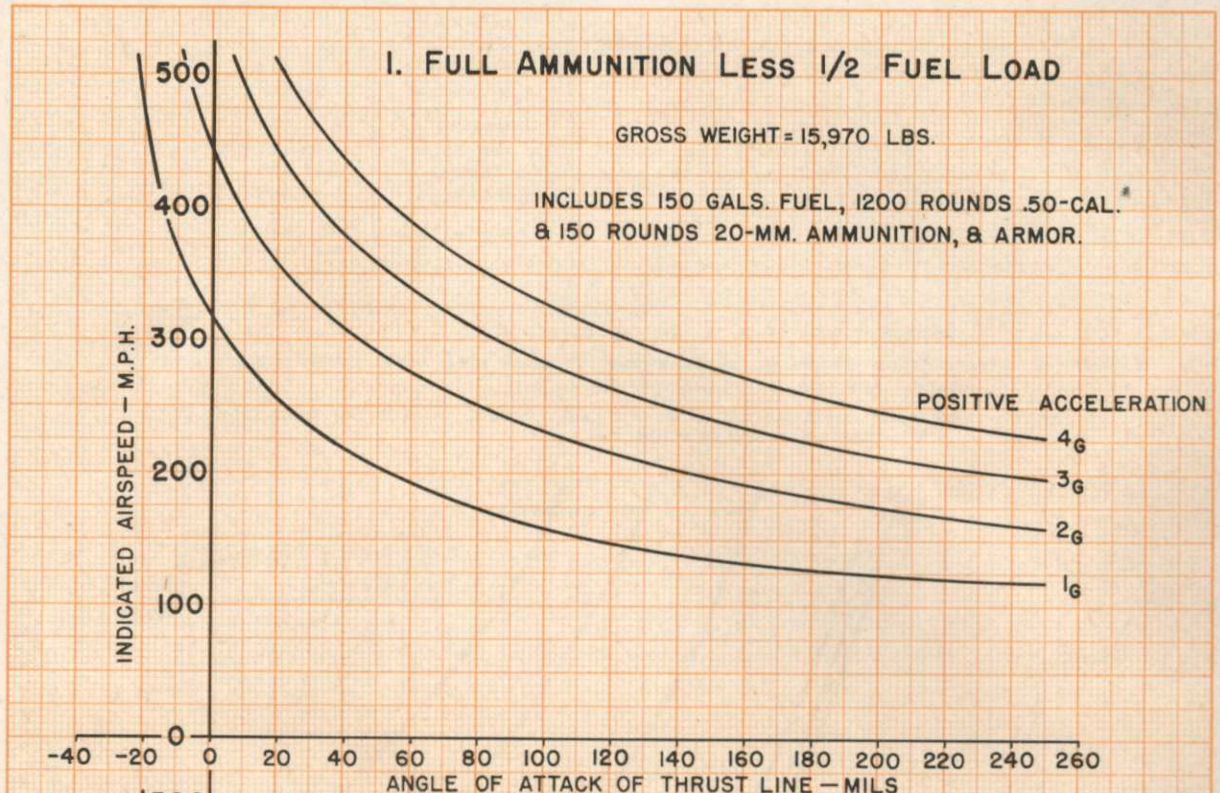


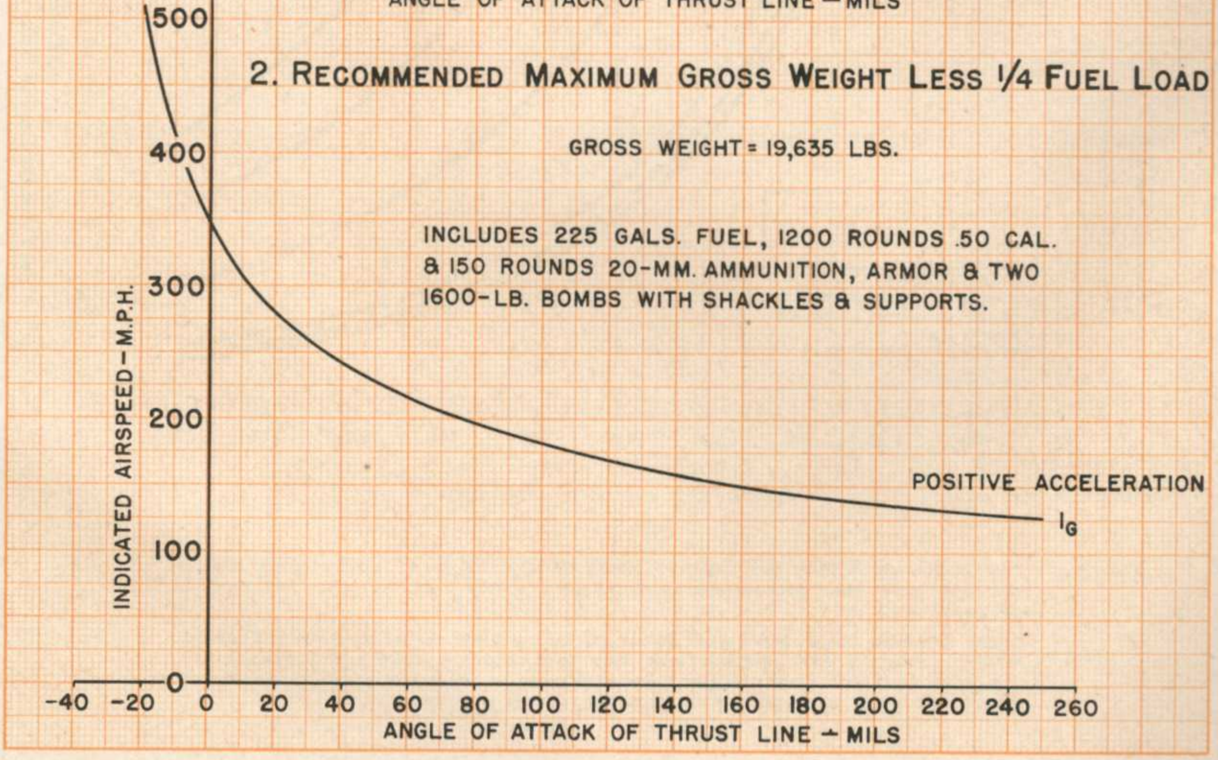
1 DEGREE = 17.8 MILS

CALIBRATED INDICATED AIRSPEED

EXAMPLE: FIND ANGLE OF ATTACK FOR 301 M.P.H. (90% OF MAX. C.I.A.S. AT LOW BLOWER CRITICAL ALTITUDE) WITH FULL AMMUNITION, LESS 1/2 FUEL, WITHOUT BOMBS, AND POSITIVE ACCELERATION OF 1g.

FROM AIRSPEED SCALE, MOVE VERTICALLY TO THE 1g CURVE REPRESENTING THE ABOVE WEIGHT CONDITION (SEE LEGEND). FROM THIS INTERSECTION, MOVE HORIZONTALLY TO SCALE AT LEFT FOR NOSE UP ANGLE OF 10.04 MILS; OR MOVE HORIZONTALLY TO SCALE AT RIGHT FOR NOSE UP ANGLE OF .58 DEGREES OR 35 MINUTES.


1. FULL AMMUNITION LESS 1/2 FUEL LOAD
GROSS WEIGHT = 15,970 LBS.
INCLUDES 150 GALS. FUEL, 1200 ROUNDS .50-CAL.
& 150 ROUNDS 20-MM. AMMUNITION, & ARMOR.
POSITIVE ACCELERATION
4G
3G
2G
1G
INDICATED AIRSPEED — M.P.H.
500
400
300
200
100
0
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260
ANGLE OF ATTACK OF THRUST LINE — MILS


2. RECOMMENDED MAXIMUM GROSS WEIGHT LESS 1/4 FUEL LOAD
GROSS WEIGHT = 19,635 LBS.
INCLUDES 225 GALS. FUEL, 1200 ROUNDS .50 CAL.
& 150 ROUNDS 20-MM. AMMUNITION, ARMOR & TWO
1600-LB. BOMBS WITH SHACKLES & SUPPORTS.
POSITIVE ACCELERATION
1G
INDICATED AIRSPEED—M.P.H.
500
400
300
200
100
0
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260
ANGLE OF ATTACK OF THRUST LINE — MILS

Cones of Dispersion

In order to harmonize fighter airplanes with a definite pattern, it is necessary to understand something about a gun's **cone of dispersion.** This cone of fire is the sum of all the flight paths of all the bullets fired from one gun.

The vibration of the gun on its mount in the wing, and the over-all motion of the airplane's wing in flight results in bullet flight path variations.

The resulting variations in the flight paths cause the bullets to scatter over an area instead of passing through the same hole. You can measure this bullet dispersion by the mil angle formed at the muzzle of the gun from the area of hits. The 4 mil cone is generally accepted and used for all harmonization computations.

For Example: A cone of dispersion for a P-38 is shown here as an illustration of a typical cone. The test was fired at 750 ft. range with cal. .50 M2 AP ammunition from the upper right gun of the P-38. These were the results:

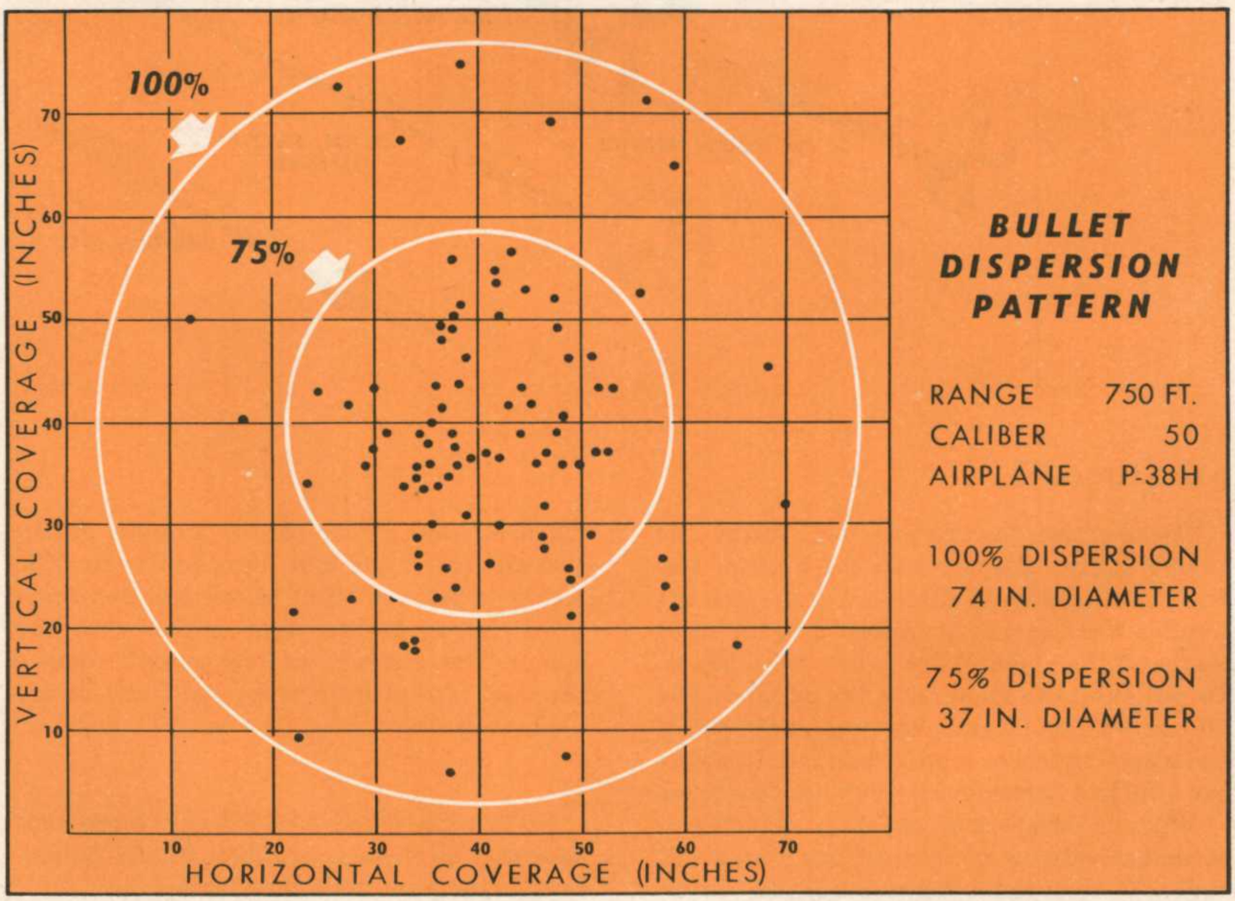
1. 75% of the hits were grouped in a 35.7 inch circle.
2. 100% of the bullets were grouped in a 71.3 inch circle.

THEREFORE this gun's cone of dispersion is:

4 mils for the 75% group
8 mils for the 100% group

The 100% cone of dispersion measures 24 ft. in diameter at a 3000 ft. range, but 75% of the bullets pass through a 12 ft. circle at that range.

The cones of dispersion for different caliber ammunition will not be the same.

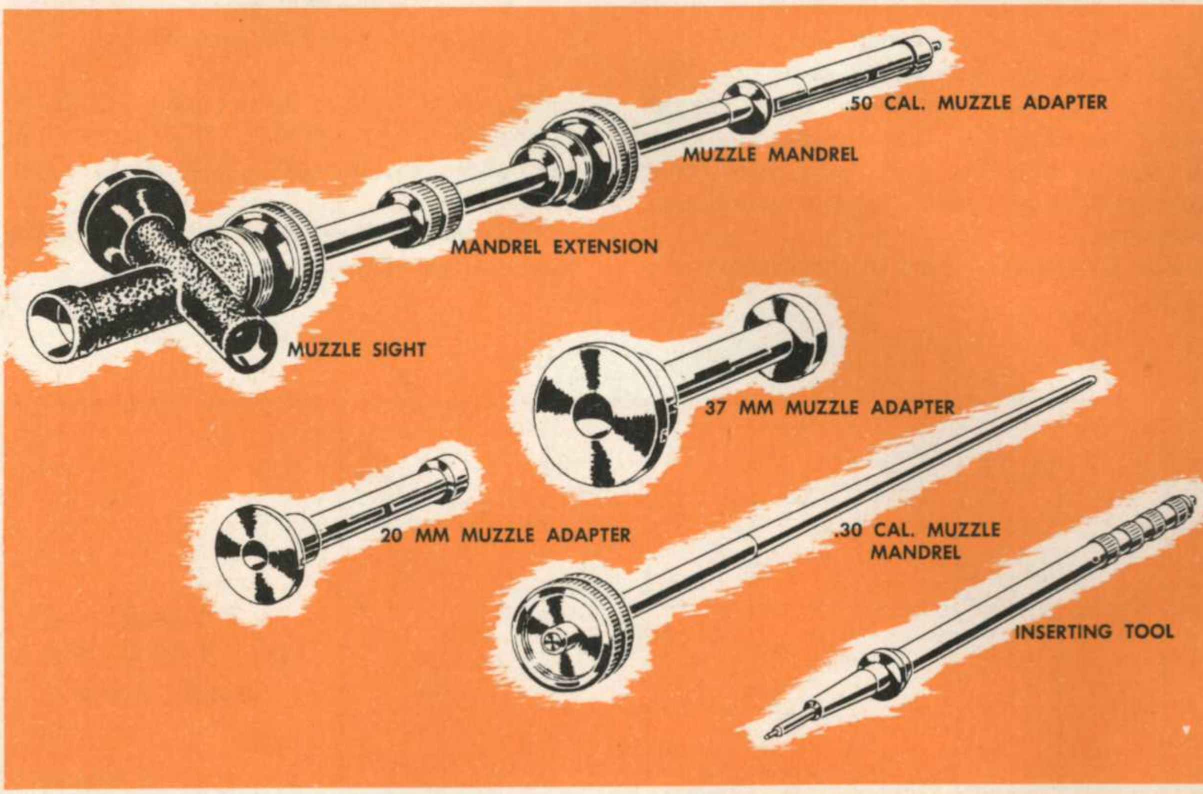


BORESIGHTING PROCEDURE AND EQUIPMENT

Adjust the sights and guns until the lines of vision, determined by the crosshairs in the boresight tool and the reticle in the gunsight, coincide as nearly as possible with their respective aiming point or points on the target.

Make sure that all sighting windows, such as windshields and bullet resistant glass, are in place when you use the boresight kit to harmonize guns and sights. Harmonize the gun and sights as accurately as possible.

This is the equipment included in the J-1 boresight kit. The individual items and authorization of kits are shown in T.O. 11-1-24.

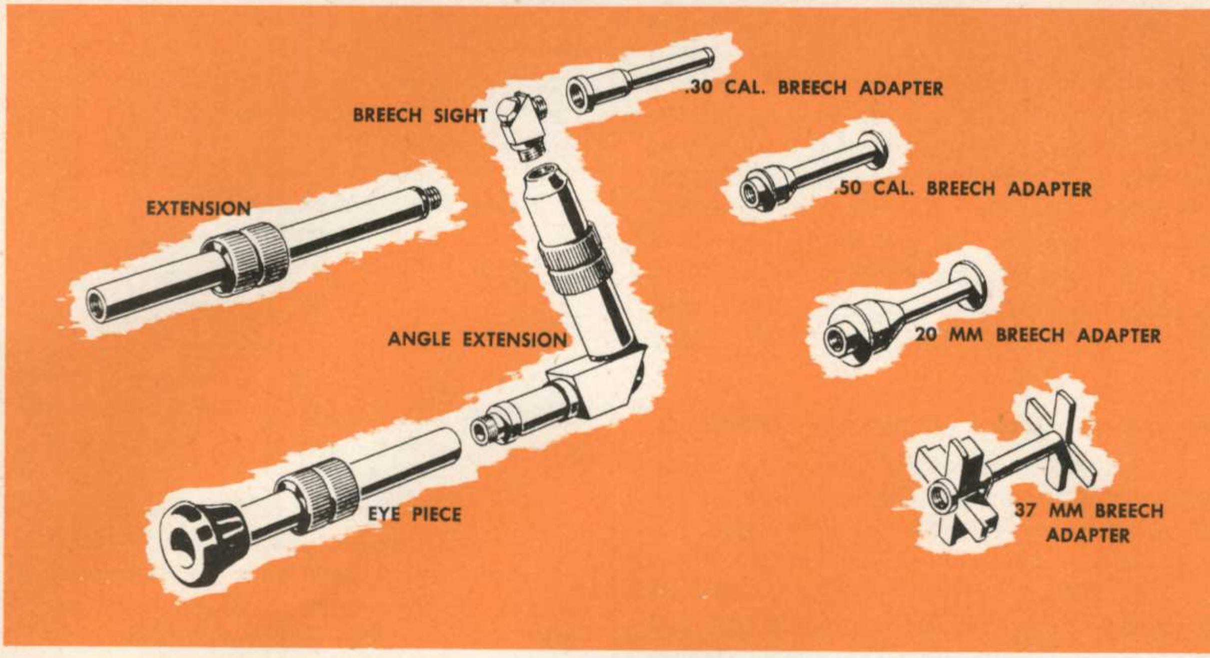


MUZZLE TOOL

To assemble the muzzle tool, insert the proper caliber adapter into the muzzle. Use the inserting tool to force it solidly into the muzzle. Next, screw the mandrel to the sight and push the mandrel firmly into the adapter. **Do not twist the mandrel in the adapter.** The .30 caliber adapter does not require the use of the inserting tool or muzzle mandrel. It is simply attached to the muzzle sight and inserted.

When a blast tube or other interfering structure extends in front of the muzzle, attach the mandrel extension to the muzzle mandrel. Then attach the sight to the extension and insert the unit into the muzzle. The reticle within the sight barrel will be visible for sighting. If the sighting-tool with the mandrel extension is not long enough, remove the blast tube or interfering structure, or use the breech tool.

NOTE: The type J-2 kit has only those tools necessary to boresight caliber .50 and 20 mm. and 37 mm. guns from the muzzle.



BREECH TOOL

To assemble the breech tool, select the proper breech adapter and screw it onto the breech sight. The wrench fits the slots in the head of each adapter. Attach the eyepiece to the breech sight. If this is inconvenient for sighting, remove the eyepiece and attach the angle extension, the straight extension, or both, to the breech sight. Then attach the eyepiece. Push the adapter firmly into the chamber, and look through the instrument to sight.

INSERTION INTO THE GUN

Before mounting the breech tool in the .50 caliber guns, lift the cover plate and charge the gun to remove any ammunition. Retract the bolt, and lock it in the rear position. Care should be taken in inserting the breech tool because an accidental release of the bolt will result in injury to the armorer and destruction of the tool. Remove the backplate if it is convenient, release the driving spring, and move the bolt rearward. If this is done there is no danger of the bolt being forced forward. The boresight tool can be inserted from above or below.

NOTE: Before inserting the muzzle tool, make sure that no ammunition is in the gun. After using the muzzle tool, be sure it is removed from the muzzle before the gun is fired.

20 MM. GUN

Remove the feed mechanism or magazine and retract the breech block, **before** inserting the breech tool. Make sure that the breech block is **all the way** to the rear and engaged by the sear. Extreme care should be taken in inserting the tool. If the breech block is accidentally released, anyone inserting it will be seriously injured and the tool will be damaged. If the 20 mm. gun is equipped with a muzzle nut, the muzzle tool can be used. But, if the weapon has a muzzle brake, the brake must be removed first.

BLAST TUBES

Make sure that the blast tube does not appear in the field of the boresight tool when boresighting fixed synchronized guns equipped with blast tubes. Remove the blast tube first, and then use the muzzle tool on these weapons.

ROCKET HARMONIZATION

The harmonization of a fighter airplane for rocket firing is very similar to the harmonization process used for aligning the airplane's guns and sight to its flight path. Actually rocket harmonization is easier because, once it is done, it is usually fixed. But unfortunately

the factors that affect the bullet in flight also affect the rocket—and to a greater degree.

It must be pointed out that a minimum of true information is available on rocket behavior at present. Little is known of the effects on their trajectories, of variations in airplane attitude, and of the effect of wind acting on the rocket when it is launched. The science of rocket firing is advancing rapidly. By the time this manual is published, certain changes may have been made in the harmonization procedure.

ROCKET AND BULLET TRAJECTORY DIFFERENCES

Rocket trajectories vary from bullet trajectories when fired under the same flight conditions. These are the principal differences:

1. Rockets are slower. The velocity of the fastest HVAR (High Velocity Aircraft Rocket) at present is approximately half that of .50 caliber ammunition. This means a longer time of flight to a given range. Therefore, greater allowances must be made for target speed and wind than in the case of machine gun fire.

2. Rockets tend to follow the airplane's direction of flight while bullets travel in the direction of aim. The bullet tends to follow closely in the direction of aim because its muzzle velocity is so much greater than the speed of the airplane. The fins on the rocket tend to align it with the airflow; and, since the launching speed of the rocket is small compared to the speed of the airplane, the rocket is quickly aligned with the resultant airflow and almost completely in the direction of the airplane's line of flight.

The less the launching speed of the rocket, the greater its deflection toward the flight path. Rockets launched from zero rail launchers align themselves almost 100% in the direction of the airplane's line of flight.

3. Rocket trajectory is very curved compared to the flatter trajectory of the bullet. This is caused by the fact that as a rocket burns it increases its velocity. As the nose of the rocket is curved down by the force of gravity, a portion of the jet force acts in the downward direction with gravitational force.

LAUNCHER ATTITUDES

The attitude of the launcher has very little effect on the dispersion. Trials have shown that even with launchers 12° out of line with the airflow, the dispersion is not significantly increased. However, you must know the attitude of the launchers to compute the correct sight settings.

FACTORY HARMONIZATION

Actually there is no need to harmonize the launcher rails on the airplane. All future installations will probably be built in at the factory or the modification center. It is planned to have all zero length launchers installed parallel to either the level lugs, fuselage reference line, or boresight datum line, depending on the term used.

This means that the launcher angle should be zero with respect to the level lugs. Furthermore, the rails should be installed so that all rockets fire forward in a line parallel to the center line of the airplane laterally. They will not be "toed in" to cross over at some harmonized range as machine guns are.

Under certain conditions the launchers may become loose or bent. If this happens, the particular zero rail has to be rebuilt and harmonized.

HARMONIZATION OF GUNSIGHT WITH FACTORY-INSTALLED LAUNCHERS

The gunsight on a fighter airplane can be harmonized for rocket firing in any manner desired. At present the usual method of harmonizing the gunsight is this:

The sight line, level lugs, or fuselage reference line, and the actual launcher line are all harmonized parallel. When this is done it may be necessary to re-harmonize the guns to this particular sight setting. This is because various airplanes are not basically harmonized when the sight line and the level lugs line, or fuselage reference line are parallel.

With this type of sight and launcher harmonization it will still be necessary to compute the sight setting required to fire the rockets at a certain speed and in a particular dive and at a given range. The gun and sight can be normally harmonized. When this is done, the sight line may not be parallel to the launcher line, but this does not affect the accuracy of fire. It means that a sight setting different from the one used with the previous type harmonization must be computed.

SECTION 5

Wing Lines

Adequate sighting and automatic releasing equipment is not yet available for use in dive and glide bombing, rocket firing, and precision strafing. For this reason it has been necessary to develop the wingline method.

From a pilot's viewpoint, the wingline method is simple. Certain principles of this method already have been used in combat; the complete method, however, is new. By observ-

ing set conditions, you can get accurate results. This method positions your airplane in a definite diving angle, at a required slant range and diving speed. The sight setting or sighting allowance is held constant for the various dive angles, and it is integrated into the system in such a manner that you do not need to estimate the proper sight settings for various dives.

Until now, diving ground attacks have been made in a haphazard manner. Inadequacy of available equipment has left a great deal up to the discretion of individual pilots, squadrons, and groups. As a result, each pilot has had his own methods of making approaches and obtaining diving angles.

Extensive tests have been made to find the most accurate method of obtaining predetermined dive angles. These flight tests covered the following approaches or positioning methods, any of which can be used to initiate a diving angle:

1. A direct push-over from level flight.
2. A 90° flat turn followed by a push-over.
3. A semi-split S.
4. A rolling split S.
5. A pull-up followed by a diving turn.

Most of these approaches have a serious drawback—you cannot get on a desired angle of dive with any degree of accuracy.

ONLY ONE APPROACH GIVES A DESIRABLE CONSISTENCY OF DIVE ANGLE. THIS IS THE SIDE APPROACH FROM LEVEL FLIGHT, WITH A DIVING TURN DIRECTLY AT THE TARGET.

A little practice in the wing line method will enable you to make accurate predetermined dives. You must start the diving turn at the moment the target appears to touch the reference mark on the wing. Tests prove that this method will result in dive angles within 2° plus or minus.

In level flight, your best vision of ground objects is always in front of the wings. Thus you get your best view of unexpected or predetermined ground objects by using a diving turn onto the target, and you need not lose sight of the target at any time during the initial approach to the diving position. This is why you should never be surprised by other airplanes appearing between yourself and the

target area, or by unexpected interference.

In high speed dives, the airplane accelerates very rapidly. A pilot's range estimation under such conditions is one of the most unreliable factors in the solution of ground attack. Proper slant range estimation is very important. In several methods employed today, slant range is found by using the altimeter reading in conjunction with the sine of the estimated dive angle. But the altimeter is very difficult to read accurately at high speeds and angles of dive. In addition, secondary sighting errors result when the pilot shifts his attention from the sight to the altimeter during the dive.

To eliminate any division of the pilot's attention, the wing line method incorporates a **time delay count** to establish a specific slant range and a specific airplane speed at the firing or release point. Estimating or counting this time delay is the most difficult pilot problem. Use of a time delay instrument would add appreciably to accuracy, but such equipment is not now available. For this reason, you must become proficient in establishing a normal counting cadence by practicing on the ground with a stop watch. This method of placing the airplane in the desired position is much more accurate and uniform than the range estimation method or the altimeter method. Accuracy of plus or minus 300 ft. slant range error is considered normal.

THE GENERAL PROBLEMS OF GROUND ATTACK

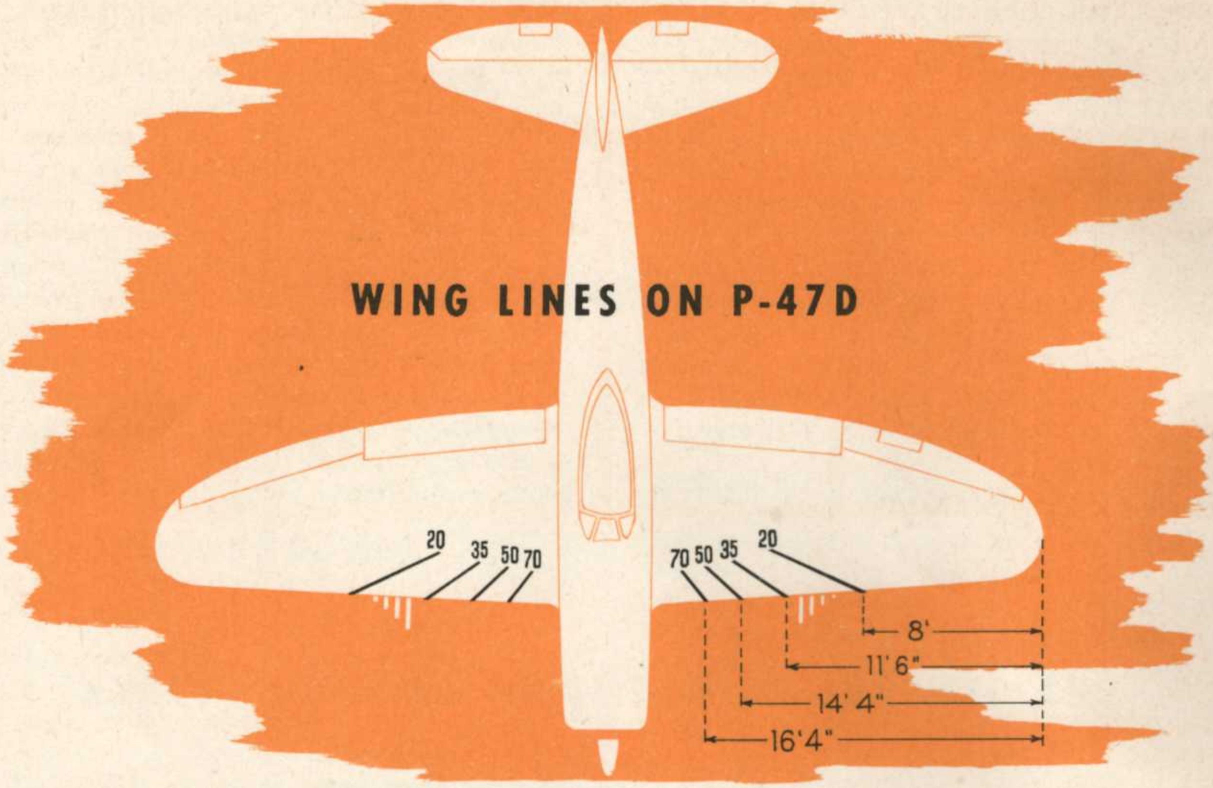
All three types of ground attack have these eight major problems in common:

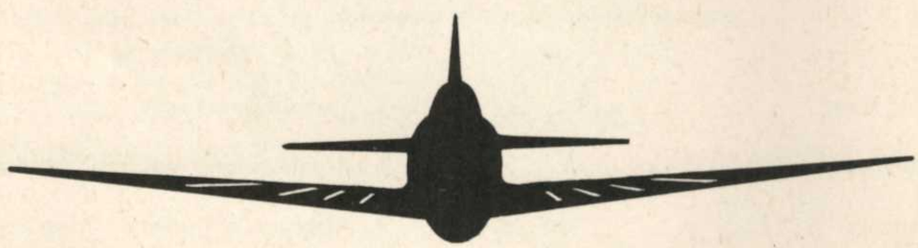
1. **Angle of dive.**
2. **Slant range.**
3. **Firing speed.**
4. **Starting altitudes.**
5. **Terrain clearance.**
6. **Accelerations required for recoveries.**
7. **Airplane attitudes at firing positions.**
8. **Sighting allowances.**

The wing line method undertakes to solve these eight problems for all three types of ground attack.

Wing Lines THEIR LOCATION ON VARIOUS TYPES OF AIRCRAFT

WING LINES ON P-47D





The dimension measurements are taken from a line projected from the wingtips along the leading edge of the wings. Use a tape to locate the proper position of the wing lines on each side. Wing line No. 20 is 8 ft. from the projected wingtip line. Wing line No. 35 is 11 ft. 6 in.; wing line No. 50 is 14 ft. 4 in.; and wing line No. 70 is 16 ft. 4 in. Wing line No. 110 would be 16 ft. 10 in. It is very hard to use this last wing line on the P-47, because it is so near the fuselage it is nearly possible to see it.

When you use these wing line locations on the P-47, be sure the gunsight harmonization speed is 250 mph and in accordance with the airplane's loading. The 6° depressed bombsight, which will be an auxiliary sight or reticle of the same dimensions as the gunsight, should be placed 6° down from the level lugs line and NOT 6° down from the harmonized gunsight level line.

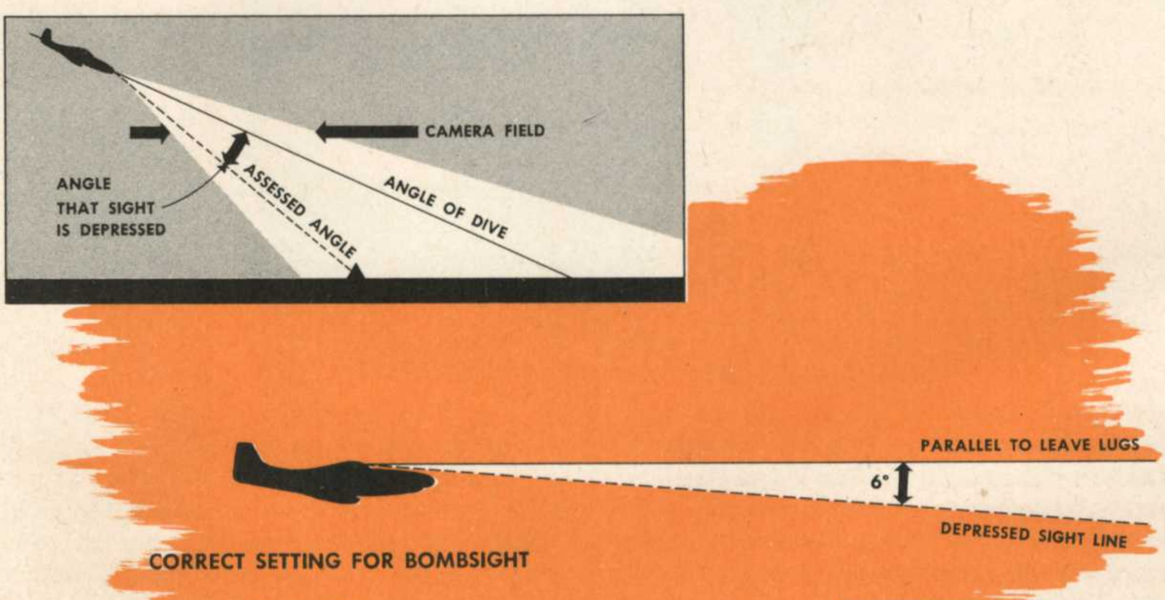
ASSESSED ANGLE OF DIVE FOR P-47 AIRPLANE GUNSIGHT HARMONIZED AT 250 MPH BOMBSIGHT ALLOWANCE 6° (FROM LEVEL LUGS LINE)

Wing Line Number	Entry Speed	Pattern Altitude	DIVE ANGLE ASSESSED		
			Guns	Rockets	Bombs
20	240	2000	22.5°	23°	27.5°
35	230	3500	32.5°	34°	38°
50	220	5000	41°	42°	46°
70	210	7000	49°	50°	54°
110	200	11000	58°	59°	63°

Notice in the table that the rocket firing position is about a degree higher than the gun firing position. This results from rapid changes in speed and angle of attack. These changes cause the dive angle to increase slightly between times of firing, as the guns are fired first at 13 seconds time delay, and the rockets at 15 seconds.

The increased dive angle for bombing is due to the 6° depression of the sight below the line of the level lugs setting. However, this angle reading is the sight line angle and not the true diving angle of the airplane. In order to find the true diving angle of the airplane for bombs, subtract the amount of depressed sight in degrees from the assessed dive angle on the gun camera film.

The following chart shows the indicated airspeeds at which you should enter the dive in order to get maximum accuracy. Notice also the time delays for gun firing, rocket firing, and bomb release, and the anticipated indicated airspeeds which these firing points will give.



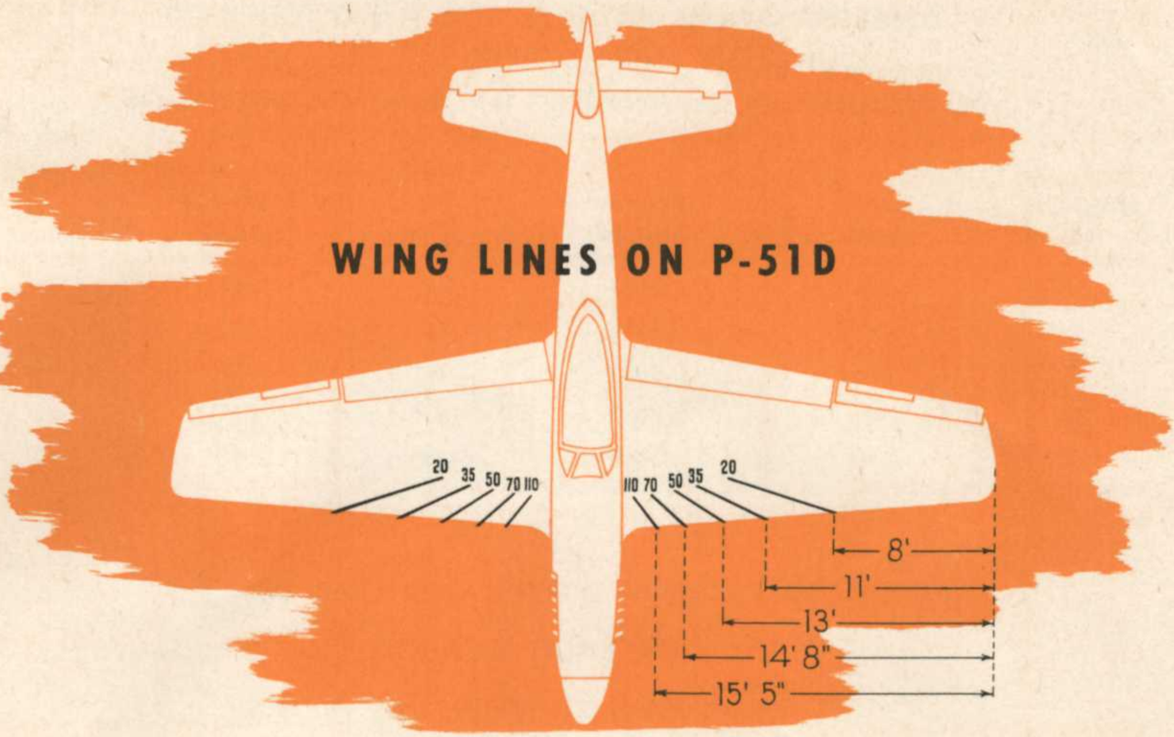
P-47D PATTERN SPEEDS AND TIME DELAY FOR EACH WEAPON

HARMONIZED SPEED: 250 MPH

W. L. No.	Altitude	Entry Speed	Firing Speed	Time Delay	Sight Allowance	Weapon
20	2000	240	290	13.0	None	.50 Cal M-2
20	2000	240	330	15.0	None	2.25" rockets
20	2000	240	330	15.0	None	5.0" HVAR
20	2000	240	350	16.0	6.0°	3.5 lb. bomb
35	3500	230	300	13.0	None	.50 Cal M-2
35	3500	230	340	15.0	None	2.25" rockets
35	3500	230	340	15.0	None	5.0" HVAR
35	3500	230	390	16.0	6.0°	3.5 lb. bomb
50	5000	220	300	13.0	None	.50 Cal M-2
50	5000	220	340	14.0	None	2.25" rockets
50	5000	220	340	14.0	None	5.0" HVAR
50	5000	220	390	16.0	6.0°	3.5 lb. bomb
70	7000	200	300	13.0	None	.50 Cal M-2
70	7000	200	330	14.0	None	2.25" rockets
70	7000	200	330	14.0	None	5.0" HVAR
70	7000	200	400	16.0	6.0°	3.5 lb. bomb
110	11000	180	285	13.0	None	.50 Cal M-2
110	11000	180	355	15.0	None	2.25" rockets
110	11000	180	320	14.0	None	5.0" HVAR
110	11000	180	400	16.0	6.0°	3.5 lb. bomb

NOTE: Time delays are based on a normally loaded operational P-47. Start counting the instant you drop the wing for the diving turn. It takes 8 to 9 seconds to make the diving turn, with the remainder of the time delay on the dive. With a 9-second turn into a dive, the airplane is on the approach dive angle for 4 seconds; then you reach the gun firing position. Two seconds later you reach the rocket firing position; one second after this, you reach the bomb release point. Maximum time on straight-away dive is 7 to 8 seconds.

WING LINES ON P-51D



On the P-51D, the dimensional measurements are taken from the projected tips of the wings. Locate the wing lines on each wing by measuring from the projected line along the leading edge of the wings. With this system of locating the wing lines, wing line No. 20 is 8 ft. from the projected wingtip line; wing line No. 35 is 11 ft.; wing line No. 50 is 13 ft.; and wing line No. 70 is 14 ft. 8 in. It is very difficult to see wing line No. 110 on the P-51; however, if it is desired, it should be located at 15 ft. 5 in.

The fixed gunsight should be harmonized at a speed of 260 mph, according to its loading chart. The 6° bombsight is an auxiliary sight with the same dimensions as the gunsight, and is 6° down from the level lugs line, and NOT 6° down from the harmonized gunsight level line. Assessing the gun camera film as in the P-47, you will find the same conditions and you can correct them accordingly, depending on the type of firing mission.

NOTE: Time delays are based on a normally loaded operational P-51. Start counting the instant you drop the wing for the diving turn. It takes 8 to 9 seconds for the diving turn, with the remainder of the time delay on the dive. With a 9-second turn into a dive, the airplane is on the approach dive angle for 4 seconds; then you reach the gun firing position; two seconds later you reach the rocket firing position; two seconds after this, you reach the bomb release point. Maximum time on straight-away dive is 7 to 8 seconds.

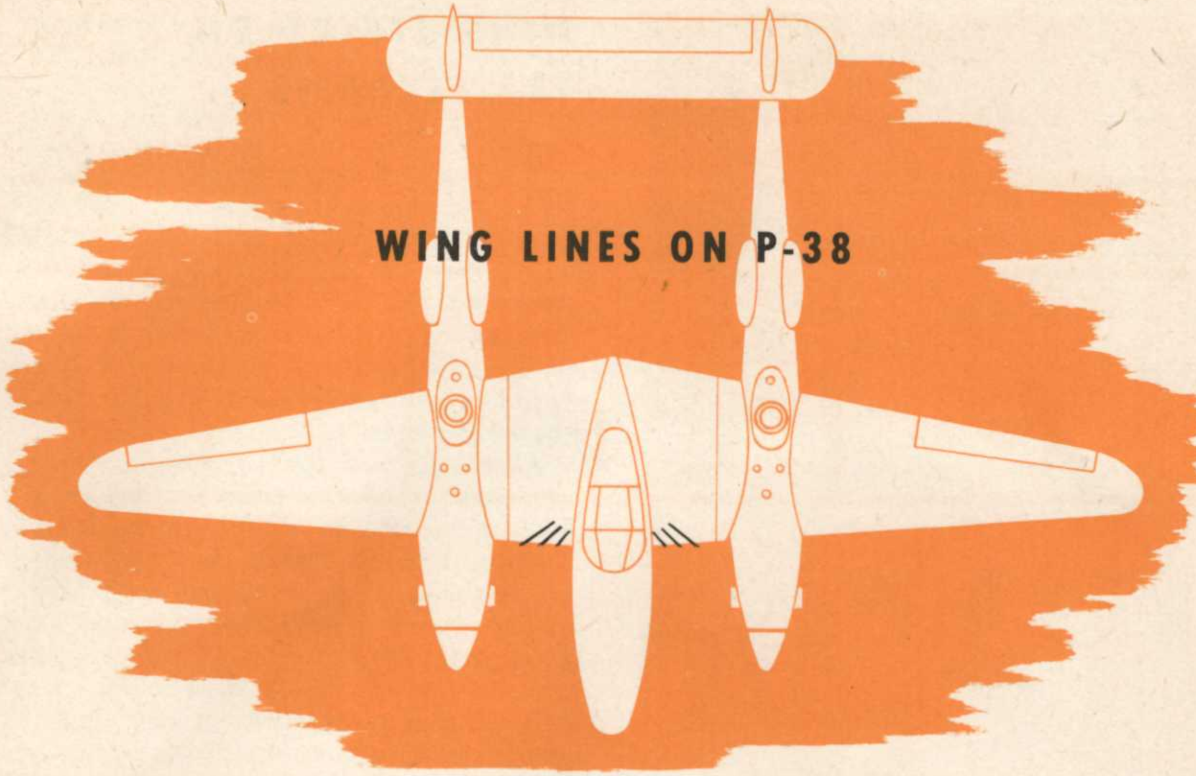
ASSESSED ANGLE OF DIVE FOR P-51D AIRCRAFT
GUNSIGHT HARMONIZED AT 260 MPH
BOMBSIGHT ALLOWANCE 6° (FROM LEVEL LUGS LINE)

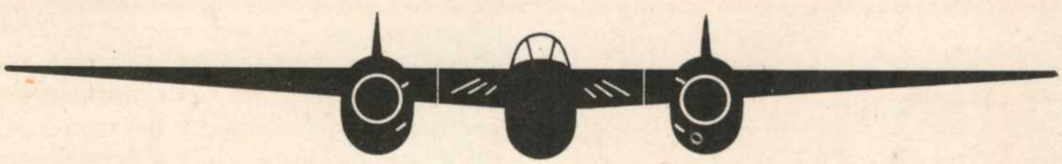
Wing Line No.	Entry Speed	Pattern Altitude	Dive Angle Assessed		
			Guns	Rockets	Bombs
20	250	2000	24°	26°	30°
35	240	3500	35°	36°	40°
50	230	5000	44°	45°	49°
70	220	7000	51°	52°	56°
110	200	11000	58°	59°	63°

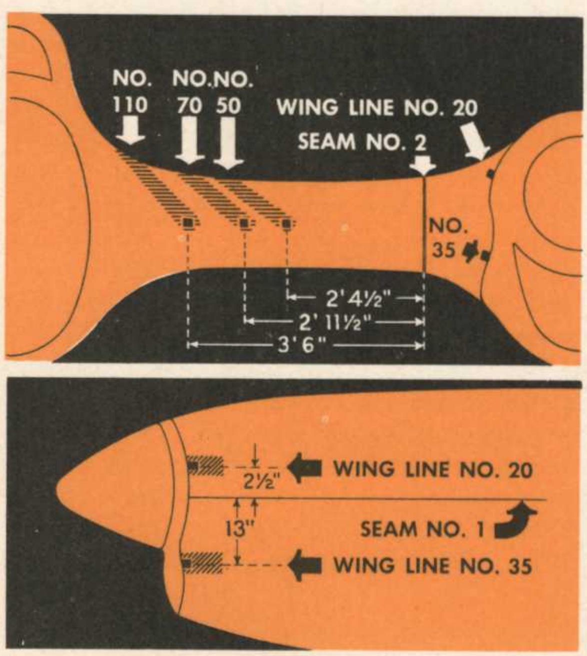
P-51D PATTERN SPEEDS AND TIME DELAY
FOR EACH WEAPON
HARMONIZED SPEED: 260 MPH

Wing Line No.	Altitude	Entry Speed	Firing Speed	Time Delay	Sight Allowance	Weapon
20	2000	250	301	13.0	None	.50 Cal M-2
20	2000	250	318	14.0	None	2.25″ rockets
20	2000	250	335	15.0	None	5.0″ HVAR
20	2000	250	352	16.0	6.0°	3.5 lb. bomb
35	3500	240	318	13.0	None	.50 Cal M-2
35	3500	240	344	14.0	None	2.25″ rockets
35	3500	240	370	15.0	None	5.0″ HVAR
35	3500	240	396	16.0	6.0°	3.5 lb. bomb
50	5000	230	332	13.0	None	.50 Cal M-2
50	5000	230	364	14.0	None	2.25″ rockets
50	5000	230	364	14.0	None	5.0″ HVAR
50	5000	230	432	16.0	6.0°	3.5 lb. bomb
70	7000	220	349	13.0	None	.50 Cal M-2
70	7000	220	392	14.0	None	2.25″ rockets
70	7000	220	392	14.0	None	5.0″ HVAR
70	7000	220	436	15.0	6.0°	3.5 lb. bomb
110	11000	210	353	13.0	None	.50 Cal M-2
110	11000	210	447	15.0	None	2.25″ rockets
110	11000	210	400	14.0	None	5.0″ HVAR
110	11000	210	447	15.0	6.0°	3.5 lb. bomb

WING LINES ON P-38

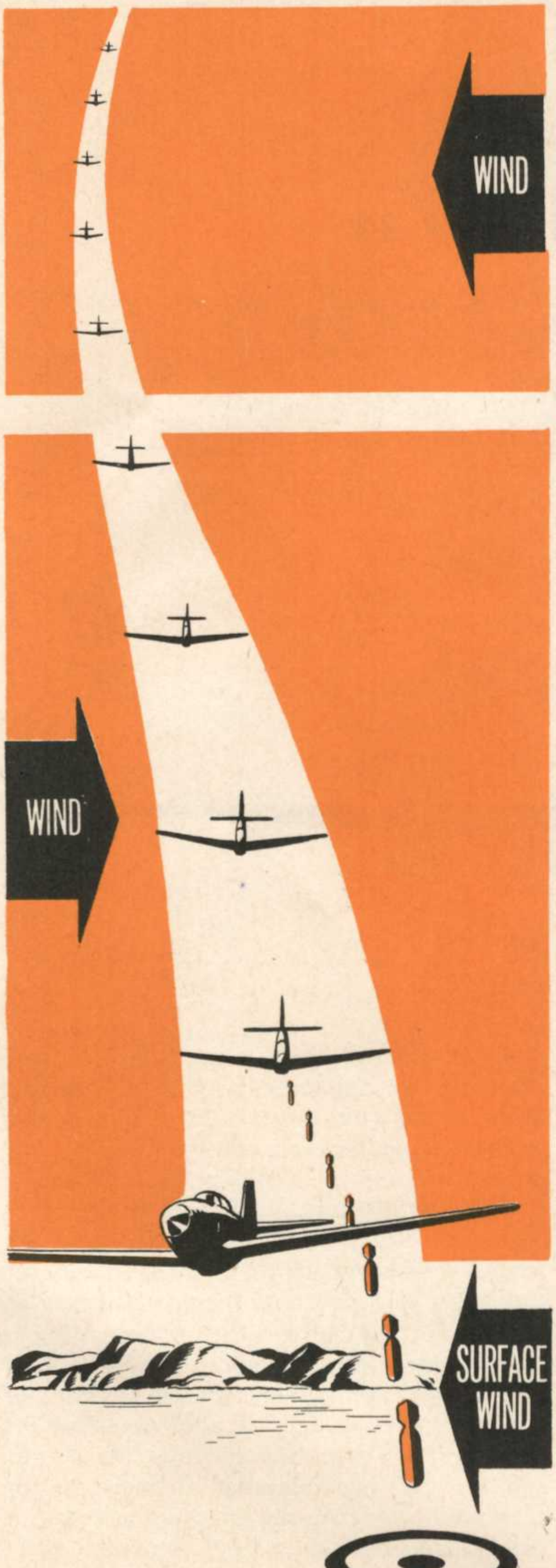






A different system is used in locating and applying the wing lines on the P-38. A careful study of the wing line positions, as indicated in the P-38 photograph, will show you the only way of locating their respective positions.

The same altitude (wing line) numbers are on the P-38. The bombsight is depressed 6°, as on the other airplanes. However, due to the unlimited visability, sight depression may be made up to 9½ degrees. But if this setting is used, these wing lines and altitudes will no longer hold true. A thorough investigation of measurements of sighting allowances for the P-38 is under way with the objective of raising the starting releasing altitudes to the maximum. For training purposes however, it is advisable to consider the 6° depressed sight as standard.



WIND EFFECT ON TRAJECTORIES

Wind effect is one of the most serious factors governing accurate firing of rockets and bomb release. This is particularly true of winds above the surface of the ground. Surface winds can easily be measured for direction and velocity, but these forces do not act on the diving airplane, and the surface winds do not have the same velocity and direction as the upper winds.

All wind corrections for rockets and bombs are based on the wind effect at a definite airspeed, dive angle, and slant range. As a result, the crosswind effect under these conditions is the maximum. However, when the airplane is diving upwind or downwind, the wind effect is proportional to the sine of the angle of dive times the velocity of the wind at the release altitude. This means that for each angle of dive the 90° crosswind effect remains relatively fixed. Headwinds, tailwinds, or target movements are proportional to the crosswind effect times the sine of the angle of dive.

In the foregoing methods, the angle of dive and the range are fixed at the initial point of the dive. The location of the firing position is affected by the wind only during the turn and the initial part of the dive. The time delay usually establishes a definite firing position.

In the case of a headwind, the range is elongated and at the same time the angle of dive is shallowed by the retarding force of the headwind. The deviation, then, is a function of the velocity of the winds. The opposite occurs for downwind dives. As a result, the wind correction necessary for upwind or downwind dives is no longer a function of the sine of the angle of dive, but is a circular correction.

Contrary to general belief, crosswind dives give as great an accuracy as upwind or downwind dives when only one type of projectile is used. Using combinations of weapons, the upwind and downwind dives are better.

SECTION 6 **Sights**

CHARACTERISTICS OF FIGHTER AIRPLANE SIGHTS

The gunsight on modern fighter aircraft must provide the aiming point not only for the guns, but also for the bombs and rockets. To employ these offensive weapons successfully, the fighter pilot should understand the care and use of the sight and see that it is always properly aligned and ready for immediate use.

A fixed sight for a fighter airplane **must** provide:

1. An aiming point, or sighting line, which can be harmonized with the airplane's line of flight and the bullet trajectories.

2. A quick method of estimating range and deflection allowance.

3. A method of sighting that will not be affected by movement of the pilot's head.

In addition, an effective sight must be adaptable to installation in such a manner that it will give:

1. Good visibility with a clear, unbroken view of the target.

2. Maximum lead allowance over the fighter's nose.

3. A convenient harmonization adjustment.

OPTICAL SYSTEMS

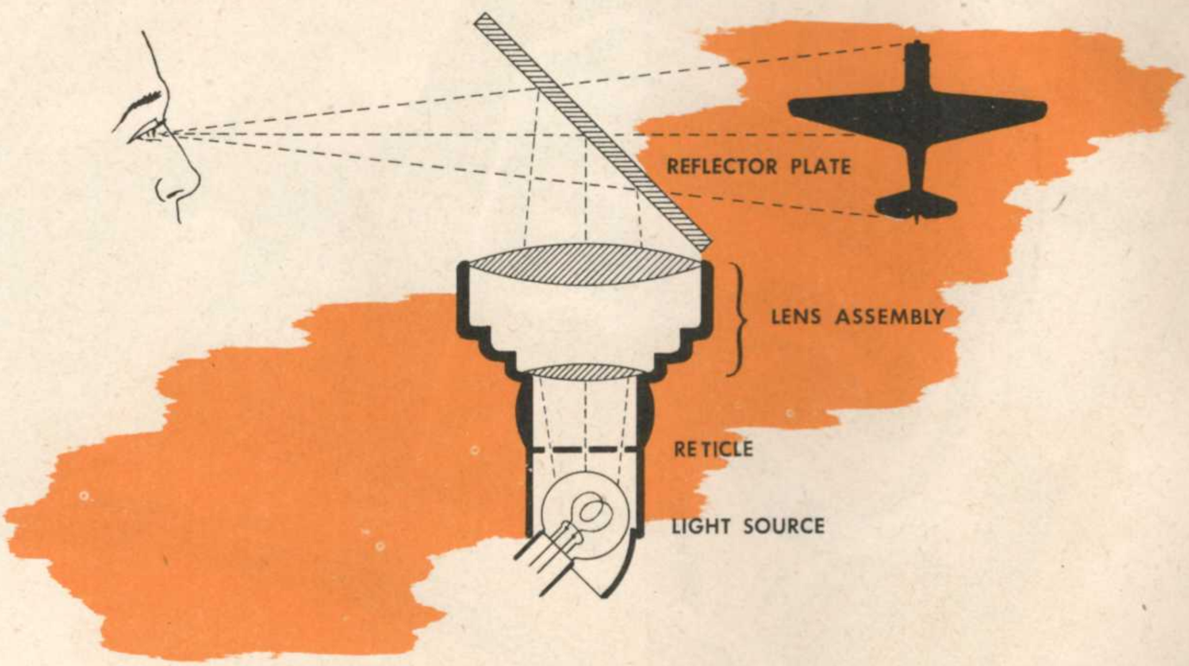
Though various types of optical sights are in use, their basic principles are the same. Whether it is a fixed sight or computing sight, there is little difference in the basic structure. As illustrated, the optical system has four main parts:

1. Light source.

2. Reticle—a ring and bead stamped from metal or etched on the back of a mirror.

3. Lens.

4. Reflector plate—a transparent mirror on which the reticle image is projected.



CARE AND MAINTENANCE OF SIGHTS

When there is a malfunction of a sight, **replace it if possible with a new sight.** In the field it is sometimes difficult to get proper glass for reflector plates, proper lenses, and other integral parts. Therefore, substitute a new sight whenever possible.

Remember that a sight is a precision instrument. It is your duty to report malfunctions to qualified maintenance personnel.

Generally, optical sights present few maintenance problems. Malfunctions do occur, however, and it may be necessary to make corrections in the field if replacement sights are not available.

DOUBLE IMAGE

This is usually caused by a cracked or optically imperfect reflector plate. Insertion of a new reflector plate usually solves this difficulty. Colored reflector plates are more likely to give double image.

MOISTURE IN SIGHT

In damp climates, moisture may collect in the sight. To correct this, the sight must be dried carefully, re-assembled, and sealed. If silica gel cells are provided on the sight, watch them closely and change them as necessary.

PARALLAX

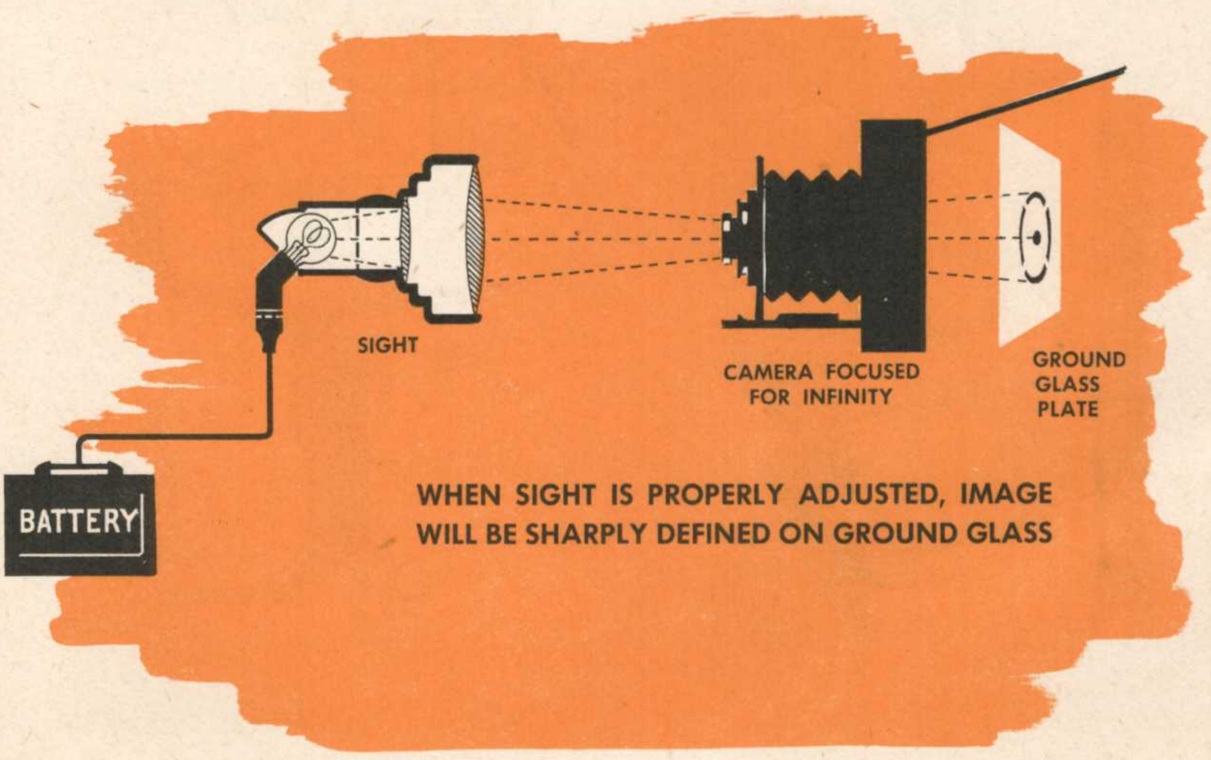
If the pipper moves away from a distant target when your head moves, parallax is present. It is caused by the sight being out of focus. In sights that permit lens adjustment, correct parallax by moving the lens to the proper adjustment. On Mk-8 sights, re-position the reticle to get the proper focus.

Check sights for parallax or double image before harmonizing the weapons. If necessary, replace the sight immediately. If a new sight is not available, eliminate parallax by adjusting the lens in this manner:

Remove the sight from the airplane and connect it to a source of power. Use a suitable camera, such as the Graflex C-3, with lens focused at infinity, the shutter open, and the diaphragm at maximum width. Place the camera so that it focuses on the reticle image. Now open the back of the camera so that you can see the image in the frosted focusing screen. Adjust the lens in the sight until the reticle image is focused sharply on the frosted camera screen. This adjustment brings the focus of the sight lens to infinity and thus eliminates parallax. If any seals are broken in making these adjustments, seal the sight unit to prevent moisture leaks.

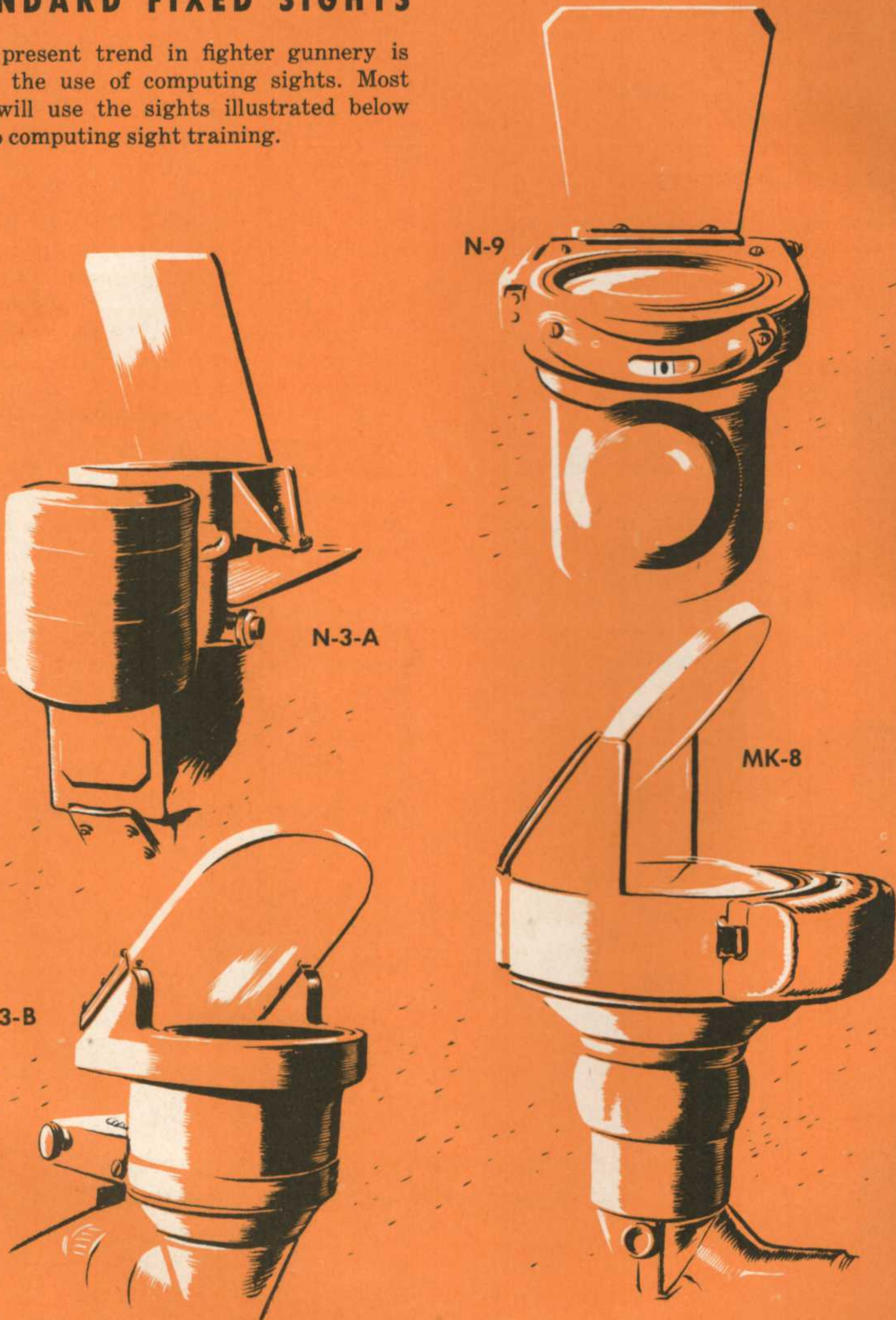
Another method of adjusting the sight lens:

If no camera is available, build a small box with a lens aperture, using a frosted screen as a view finder in the opposite side of the box. Place in the aperture a lens that is equal or superior to the lens in the sight. Focus the box lens on a distant object until it appears clearly defined on the frosted screen. This can be applied to the sight in the same manner as the camera described in the foregoing paragraph.



STANDARD FIXED SIGHTS

The present trend in fighter gunnery is toward the use of computing sights. Most pilots will use the sights illustrated below prior to computing sight training.

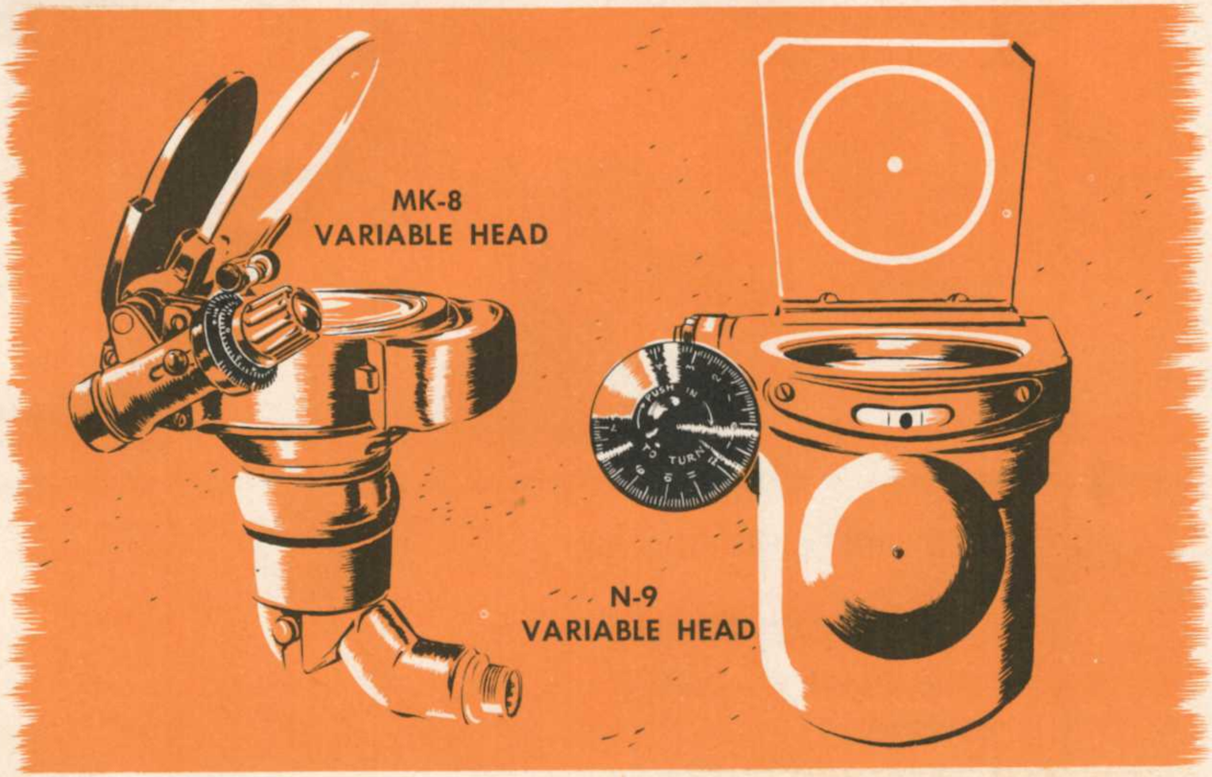


FIXED SIGHTS WITH VARIABLE REFLECTOR PLATES

These include the Mark VIII with variable head, and the N-9 with tilting head.

The tilting reflector plate provides an aiming point for bombs. Adjusting the dial to a predetermined sight setting causes a movement of the tilting reflector plate. This changes the position of the sight line.

Sights are affected by jolts and wear; check their settings' accuracy frequently. It is vitally important to know at all times whether the sight returns to the proper gun harmonization position. Only one reflector plate setting results in accurate gun fire. Any dial movements for bombing make the sight ineffective for aiming the guns until you return the pipper to its former position.



ADAPTATION FOR N-9 SIGHT

There is a simple method of providing a sight line for use during bombing runs without disturbing the normal gunsight setting. This method can be adapted to any fixed sight, even under field conditions.

Use a reflector plate from a discarded sight, or cut a piece of optical glass to fit the reflector plate on the sight. Mount this plate on the front side of the sight reflector plate. **Note:** the front side is the side farthest from the pilot. Two bolts hold the plate in place. Mount the bolts with springs to provide a hinging action of the lower portion of the reflector plate.

The control bolt is at the upper end of the reflector plate. It extends through the added reflector plate and makes contact with the original glass provided in the sight. Turning this bolt forces the added reflector plate away from the original glass, because of the hinging action of the springs.

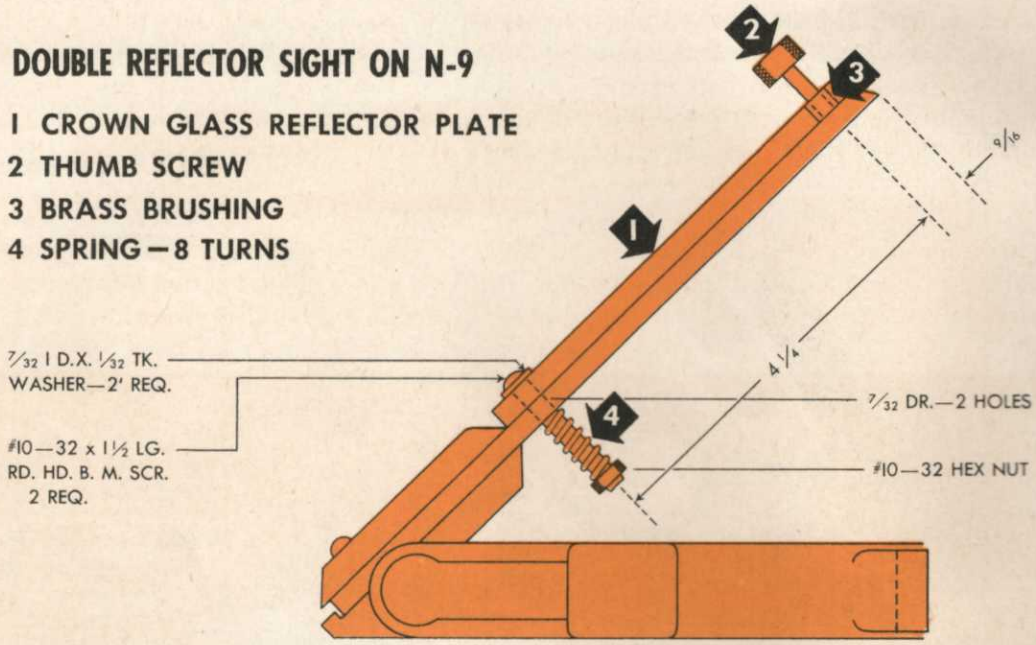
The added glass provides another reticle image. When the two reflector plates are flush, only one reticle image is visible. This provides the harmonized sight line for machine gun fire. By forcing the upper reflector plate away from the original sight plate, an extra reticle image is added. Turning the control bolt lowers

this image to any desired bomb setting. This supplies you with a bombsight, and you still have a gunsight ready for immediate use.

NOTE: Because of the necessary thickness of the optical glass, a third reticle image is discernible. This should cause no difficulty. When the reflector plates are flush, you can see only one image. When the sight is adjusted for the bombing run, you cannot see the third image.

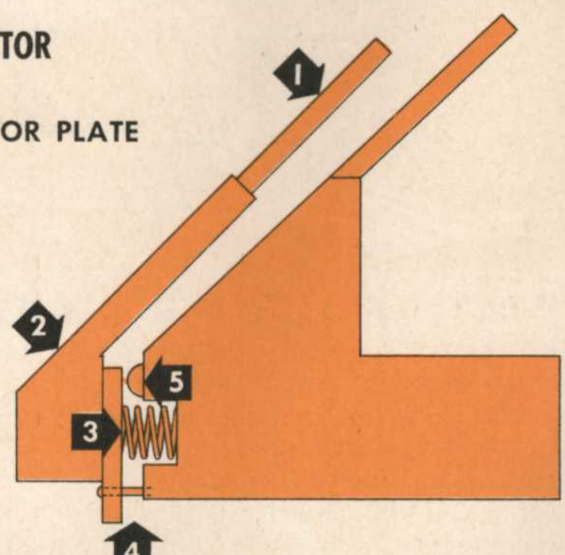
DOUBLE REFLECTOR SIGHT ON N-9

1 CROWN GLASS REFLECTOR PLATE
2 THUMB SCREW
3 BRASS BRUSHING
4 SPRING—8 TURNS



MK-8 WITH DOUBLE REFLECTOR

1 CROWN GLASS REFLECTOR PLATE
2 SUN SHADE BRACKET
3 SPRING
4 ADJUSTMENT SCREWS
5 ROCKER



ADAPTATION FOR MK-8 SIGHT

Only three items need be added to the Mk-8 sight to furnish a double reflector.

Use reflector from a discarded sight, or cut one from optical glass to fit the sun shade bracket. Substitute this reflector plate for the colored glass in the sun shade assembly.

Add a semi-circular bar to the sight housing to serve as a rocker for the sun shade assembly.

Mount a spring in the aperture provided in

the sight housing. This creates a tension between it and the sun shade assembly.

Adjust the added reflector plate to the desired image setting by means of the lower pair of screws in the sun shade assembly.

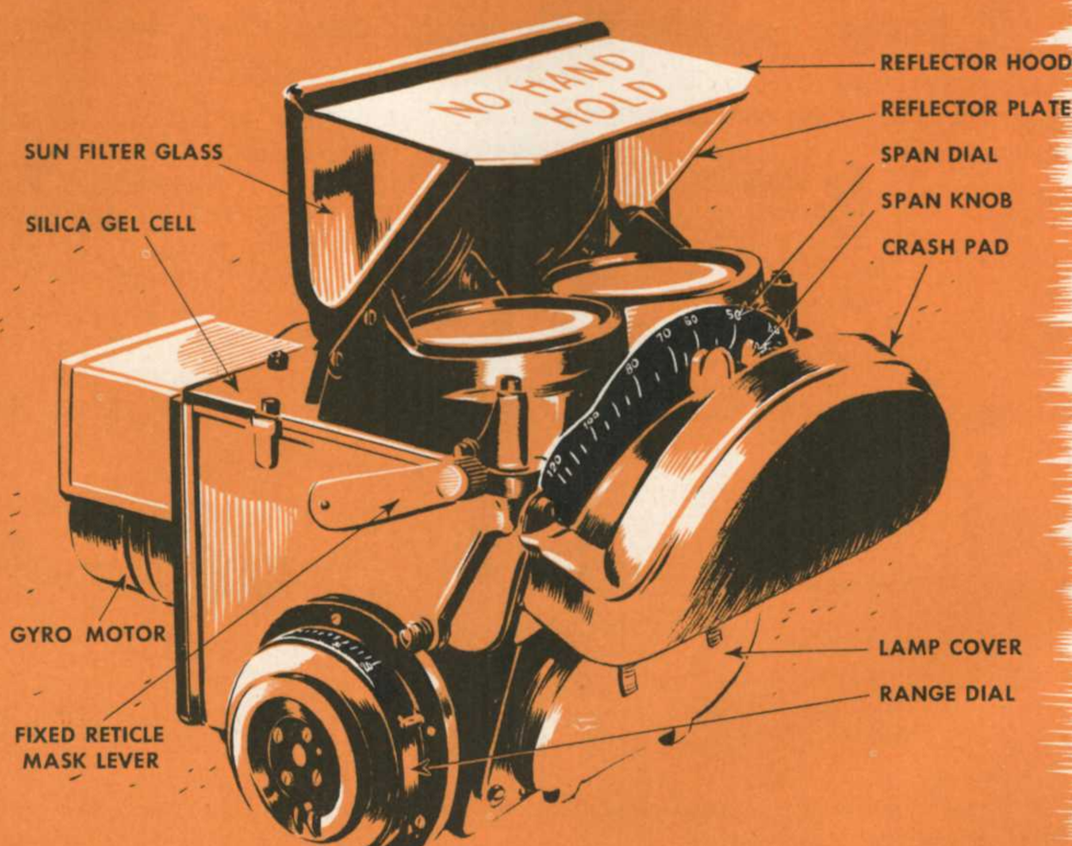
During normal use of the sight, the added reflector plate is at the left, and only one reticle image is visible. Before making a bombing run, rotate the extra reflector plate into position ahead of the normal reflector plate. This gives you a bombsight as well as a gunsight.

IMPORTANT: Only one predetermined depressed sight setting can be used while in flight. The adjustment of a desired sight setting must be done on the ground.

COMPUTING SIGHTS

Since computing sights operate on basic gunnery principles, you must have a thorough knowledge of gunner problems. This is particularly true of the present computing sights, whose accuracy depends greatly on your manipulation of the sight controls.

K-14 COMPUTING SIGHT



The K-14 sight consists of two sights built into one housing, each sight having an optical system of its own. You see the standard fixed sight with your left eye. **The reticle image consists of a 71.12 mil circle and a center cross.** The fixed sight is used for harmonization, maintenance checks, and as a stand-by sight.

The gyro sight, seen by your right eye, is designed on the same basic optical principles as the fixed sight. It employs two superimposed reticles, so that the resultant image is a circular design of six diamond-shaped images and a central dot. The image is projected to a rotating mirror, which determines the position of the reticle image on the reflector plate.

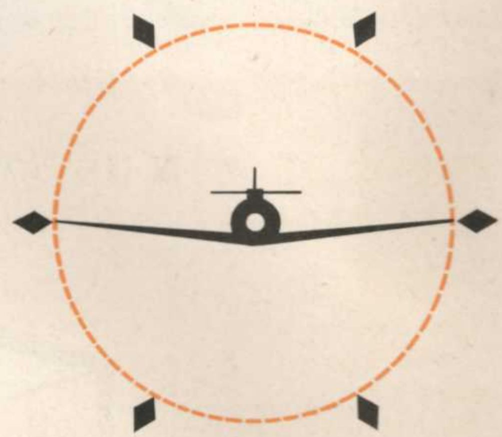
The sight operates on two induced factors—angular velocity (target speed) and range (bullet's time of flight). The attacking fighter's rate of turn determines the angular velocity. You must track the target for at least one second before firing, keeping the pipper exactly on the target. It takes the sight one second to start computing accurately.

The pilot operates these controls:

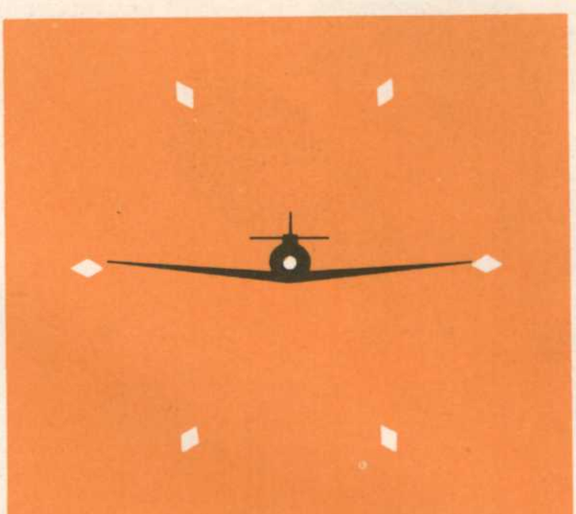
1. Span setting knob. The dial is calibrated in feet or by types of enemy airplanes. Set the knob to correspond to the target's wingspan, thus varying the image's diameter. Example: For a FW-190 with a 34½ ft. wingspan, set the knob at 34½ ft., or at the "FW-190" setting.

2. Selector-dimmer control. This control varies the brightness of the images. You also can select a fixed sight, gyro sight, or a combination of both.

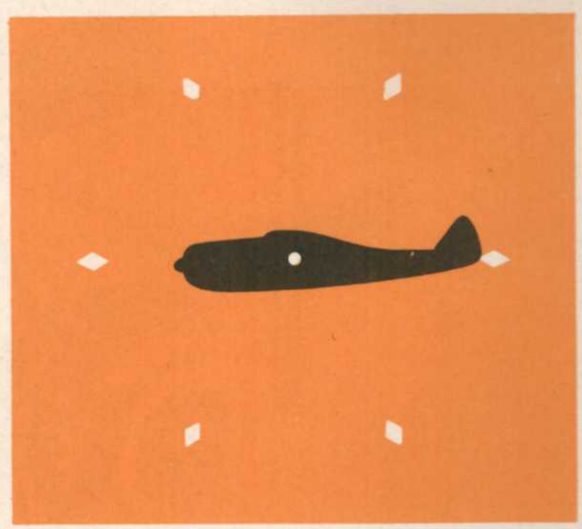
3. Twist grip. This control is mounted on the throttle handle. It varies the size of the image and computes range by subtending the wingspan. The reference point for ranging is an imaginary circle formed by the diamonds' **inner points.**



Target wingspan foreshortens as the angle off decreases. Therefore:

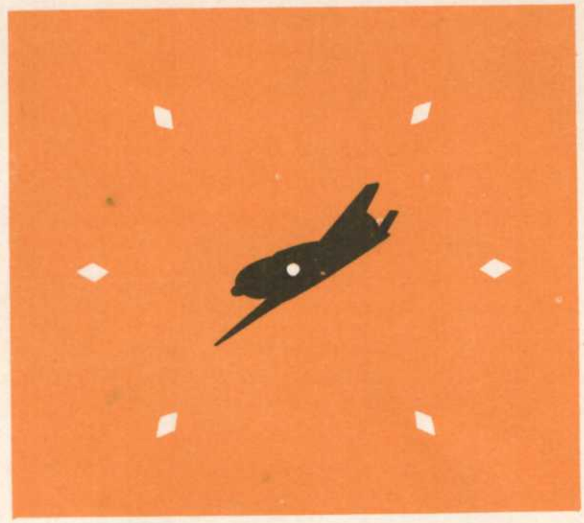


1. On overhead, head on, and dead astern attacks, the imaginary circle should touch the 12 Sights wing tips.



2. On beam attacks, place the pipper on cockpit with the circle touching the tail.

3. At other angles, make the circle larger than the apparent wingspan. A general rule to follow is to allow 1/10 of a diameter on each side.



NOTES ON USE OF K-14 SIGHT

1. To minimize lag in the sight and to afford easier tracking at the start of the pass, leave the twist grip in the forward position—600 ft. range.

2. Highly evasive targets are hard to hit, because the rapidly changing ranges require constant use of the ranging control.

3. The sight is more effective at small angles and tends to suck you into a stern chase. The sight tends to under-lead at deflection angles above 45°. Effective firing range is within 1500 ft., as the sight under-leads at long ranges.

4. The sight does not correct for mush.

HARMONIZING THE K-14 SIGHT

The two reticle images must be superimposed. To do this:

1. Remove silica gel cell.

2. Turn the two screws in the back of the sight head to obtain vertical and horizontal adjustment of the fixed mirror.

3. Adjust these screws until the center of the fixed cross coincides with the pipper of the gyro image.

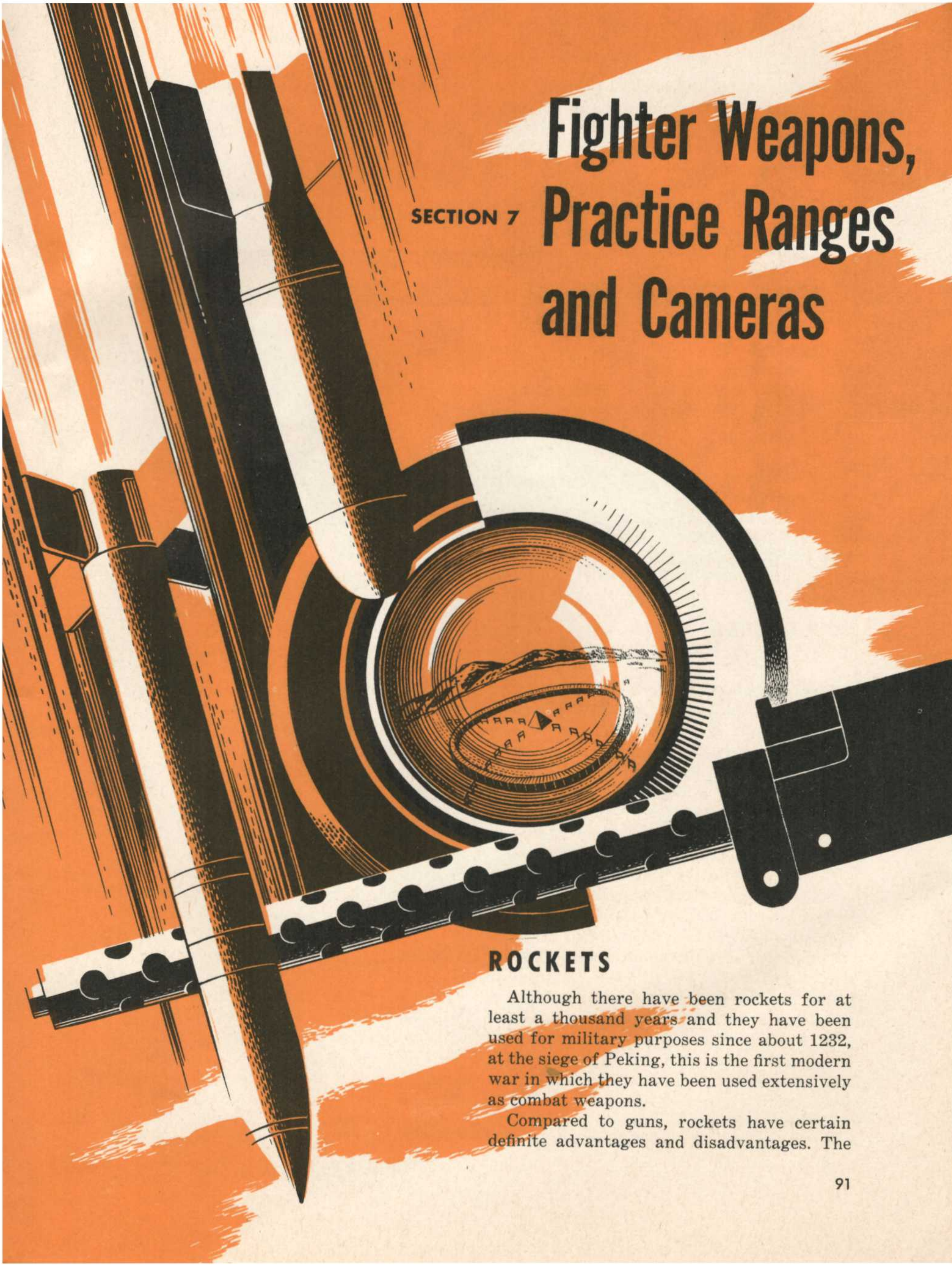
The mounting bracket has a differential toothed arrangement for both large and small movements. This arrangement makes it possible to adjust the sight harmonization within an accuracy of two mils. It is necessary to move the rings in relation to each other. A movement of one large tooth causes a displacement of 10° in the sight line. A movement of one small tooth provides a displacement of 3.3°. **Example:** Move the sight head and ring one large tooth. Then move the sight head three small teeth in the opposite direction. This results in a total movement of one-tenth of a degree.

TESTING THE K-14

1. To see whether the sight is working properly, fly in a circle at a constant rate of turn.

2. Rotate twist grip slowly. When you see a small image, it should lag farther behind the fixed sight than when you see a large image.

3. If the sight is not operating as it should, have it repaired only by competent personnel. Do not undertake anything beyond external repairs and cleaning. Improper handling of the sight destroys its calibration.



SECTION 7

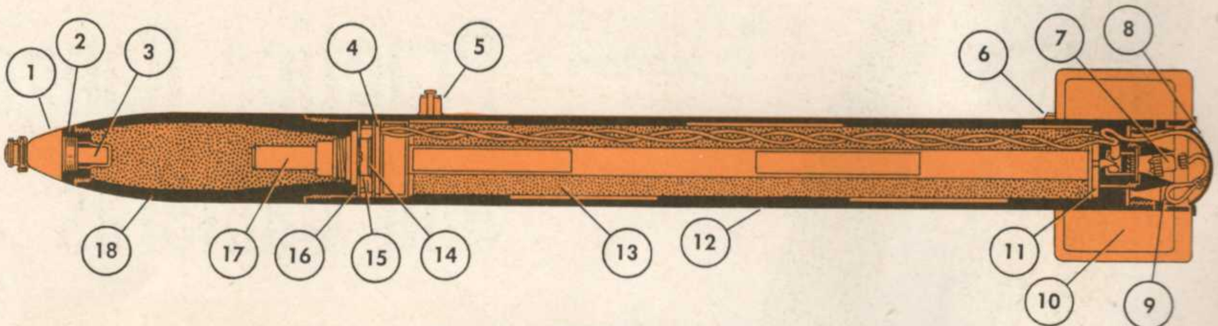
Fighter Weapons, Practice Ranges and Cameras

ROCKETS

Although there have been rockets for at least a thousand years and they have been used for military purposes since about 1232, at the siege of Peking, this is the first modern war in which they have been used extensively as combat weapons.

Compared to guns, rockets have certain definite advantages and disadvantages. The

advantages include: no recoil on the launching structure, low cost, simplicity, and portable launchers. Rockets give the fighter airplane the destructive power of a light cruiser. Their greatest single disadvantage is their extreme sensitiveness to airplane maneuvers. The rocket's relatively slow speed results in greater impact errors.



5.0 HVAR. SECTION DRAWING

1. FUZE
2. FUZE LINER ASSEMBLY
3. BOOSTER CUP
4. IGNITER
5. LUG BUTTON
6. SUSPENSION MOUNT
7. WIRE AND PLUG
8. REAR SEAL
9. NOZZLE SEAL
10. FIN
11. GRID
12. MOTOR TUBE
13. PROPELLANT GRAIN
14. FRONT SEAL
15. FELT SEAL
16. FIBER SEAL
17. BASE FUZE
18. BODY

HOW ROCKETS WORK

The typical aerial rocket is composed of: motor tube, propellant and igniter, grid, nozzle, fins and head (payload and fuse).

An electric circuit closes when you squeeze the trigger. This sends an electric current through the squib (similar to a blasting cap), which ignites the black powder. This powder fills the interior of the motor tube with a sheet of flame. The fire ignites the propellant and increases pressure to operating force. The burning propellant generates a large quantity of hot gas. The gas pressure inside the tube quickly rises to a value determined by the characteristics of the propellant and the size of the orifice. The gas exerts approximately the same outward force on each square inch of area on the inside of the tube. However, since there is an opening at one end of the tube, the gas rushes out without exerting any force on the area at the opening. At the same time it exerts its full force on the area at the closed end of the tube.

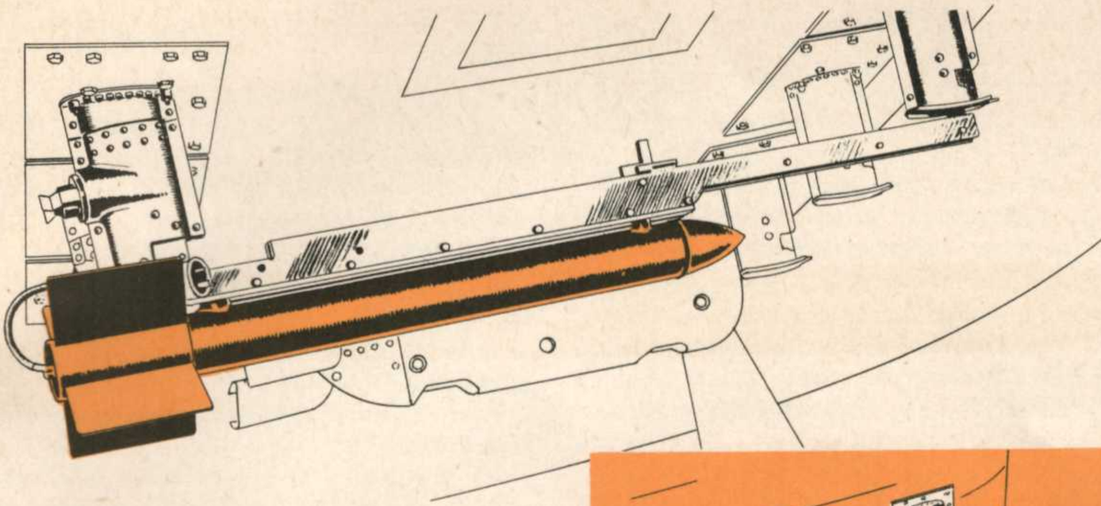
In this manner a propulsive force is produced which acts in the direction away from the open end. The rocket immediately begins to move forward on its launcher, which momentarily guides it in the proper direction.

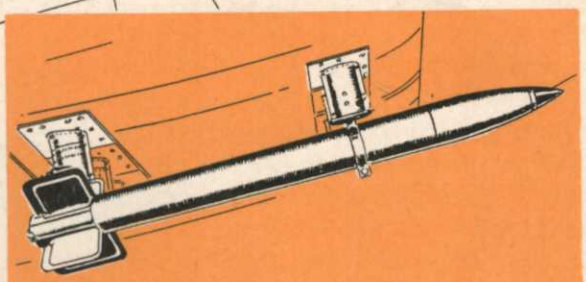
The propellant is in stick form and is called **ballistite.** Ballistite has a 52% nitrocellulose base and a 43% nitroglycerine base. It burns slowly and evenly. Burning time of typical American rockets ranges from about 0.15 seconds to as much as 1.5 seconds, depending on the web thickness of the grain and the propellant temperature. Burning distances range from a few feet to several hundred feet. Therefore, most of the propellant burns after the rocket has left the launcher.

The grid supports the powder grain before and during burning. At the same time it allows enough clearance for the gas to flow from the propellant to the nozzle.

The nozzle has two functions. (1) It directs the gas jet in the desired direction. (2) It provides for expansion of the hot gas in the exit cone, and gives about 33% more thrust than is obtainable from a simple orifice.

The fins give the rocket stability in flight, prevent tumbling, and insure head-on impact.





5.0 HVAR ON ZERO LENGTH LAUNCHERS

TRAINING ROCKETS AND LAUNCHERS

The 2.25 in. sub-caliber practice rocket, known as SCAR, can be fired from the standard zero-length launcher by using the M-6 rail adapter. The SCAR is 29 in. long, weighs 11.8 lbs., and attains a velocity of about 1130 ft/sec., plus the velocity of the firing airplane. Lampblack will soon be included in all 2.25 inch SCAR shipments. Used in the venturi, this lampblack aids spotting.

The zero-length rail is the most widely used launcher. The rocket lugs slide into the slots on the two posts. The launcher simply holds the rocket in firing position. The rocket is fired electrically by means of a squib and an igniter within the rocket. These are connected by a pigtail, to a plug in the rear of the launcher mount.

On the zero-length launcher, the rocket is slipped on from the front. A latch engages the lug and a light shear wire holds it in place. A heavy wire holds the Mark-6 rail adapter permanently in place. The 2.25 in. rocket slips onto the rail and is held by a light shear wire. Be sure to insert the proper strength shear wire to prevent the rocket from damaging the launcher assembly or the aircraft wing when fired.

A selective-firing control box, or intervalometer, is installed in the cockpit. This permits you to fire the rockets singly, in salvo, or in any desired number up to the salvo, with either instantaneous or delayed fusing. The fuse selector is an arming solenoid in the front launching post. It controls the "arm" or "safe" settings of the nose fuse in the body.

HANDLING AND LOADING PRECAUTIONS

Aircraft rockets, like any other high explosive ammunition, must be handled and stored carefully. They should be stored separately from other ammunition in a cool, dry place. Store explosive heads separately from motors. **All fire precautions must be taken.** Handle rockets with care—not only from a personal safety standpoint, but because if a motor is dropped, the propellant grain may be broken or cracked. In this case, burning

will be more rapid, causing pressure to develop more quickly. This can result in the motor body rupturing, or in a premature explosion and substantial damage to the aircraft wing.

Common sense rules will prevent burred threads, distortion of components, etc. Vehicles carrying rockets should be marked plainly, and loading areas selected so that any surrounding buildings or equipment cannot be damaged. **The blast of a rocket is dangerous as much as 200 ft. to the rear!**

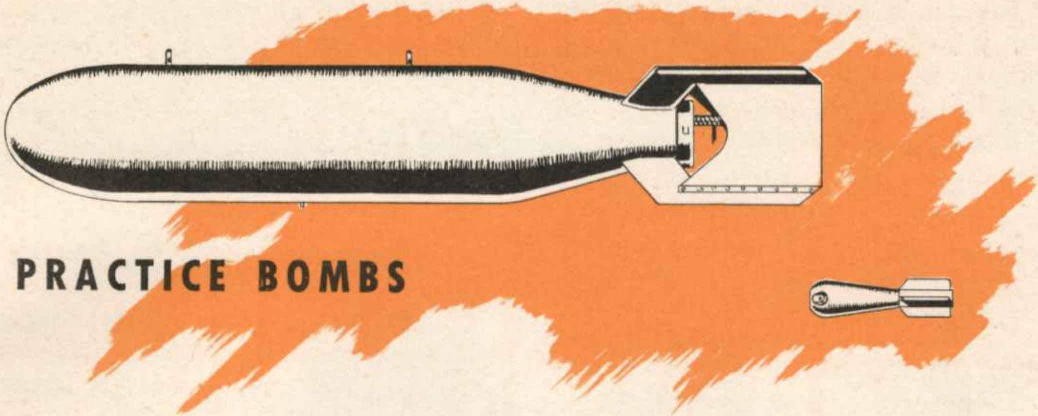
All rocket motors have the firing temperature limits stenciled on the side. These are the temperature limits for which the propellant has been designed. **They should not be exceeded.** If the temperature goes above the maximum limit, the gas pressure generated on firing may exceed the ability of the motor to contain it. A motor burst can damage the firing airplane. If the temperature is too low, the rocket may not fire. Any extreme temperature variations will materially affect the ballistic qualities of the rocket.

For both pilots and crew members, the loading procedure is one of the most important parts of rocket firing. Learn these steps and **follow them:**

1. Park the airplane in a clear area.
2. Test all circuits to be sure the correct one is closed when the firing switch is depressed.
3. Be sure all switches are OFF.
4. Check circuits again to be sure there is no residual voltage.
5. Assemble rockets.
6. Be sure the temperature is within the specified limits.
7. A safety officer will inspect launchers, fittings, etc.
8. Ammunition truck and loaders leave the area after rockets are loaded.
9. A safety officer will inspect the installation again.
10. With all starting switches **ON** and all rocket switches **OFF**, make a last check to be sure no residual voltage is left in the rocket circuit. This is a most important check, because **one volt and one-half amp. will fire the rocket.**
11. One crew member removes the shorting clips and plugs in the pigtails.

The pilot's main concern in the foregoing steps is that he may act as the safety officer. It is logical that he should check the rocket launchers and fuses, so that all equipment will function properly.

The pilot also is responsible for cockpit switches during the circuit checking and loading procedure.



PRACTICE BOMBS

Practice bombs that simulate service bombs meet training requirements. Practice bombs function similary to service bombs, but contain just enough explosive for spotting purposes. The charge produces a smoke enabling spotters to score the hits.

There are several different types of practice bombs—the 3 lb., AN-Mk5 Mod 1 shown here is a one-piece die casting. The cartridge or spotting charge is usually located in the nose and along the axial center of the bomb. If the cartridge does not explode when the bomb is dropped, only trained personnel should remove or detonate it. Practice bombs should not be dug up by hand unless inert. A nearby explosion from a small practice bomb cartridge can cause serious injury.

For more detailed information on the subjects of bombs and fuses, fusing, penetration, minimum release altitudes, horizontal blast areas, etc., refer to the AAF Board report "Selection of Bombs and Fuses for Bombardment Targets" dated 18 October 1944; Technical Manual 9-1907, subject "Ballistic Data, Performance of Ammunition" dated 23 September 1944; Technical Manual 9-980 "Bombs for Aircraft" dated 23 September 1940; T.O. 11-25-12, subject "Bombs — Minimum Altitudes of Release and Pre-arming of Fuses" dated 7 May 1943.

MACHINE GUNS AND CANNON

Adding rockets and bombs to fighters has so greatly increased their destructive power that there may be a tendency to minimize or overlook the machine guns, which are still the basic fighter weapon.

Automatic guns of 37mm, 20mm, .50 cal.

and .30 cal. are in use at present, but the most widely used weapon for fighters is the Browning Machine gun, cal. .50 M-2. It is recoil operated, belt fed, and air-cooled. The metallic link disintegrating belt is used in all firing. This gun is capable of firing about 800 rounds per minute, but since the supply of ammunition is limited, you will have the following time of firing with **maximum ammunition load:**

Type Aircraft	Time	Armament	Capacity
P-40	22.1 seconds	6 Cal. 50	281 rds/gun
P-47	21.6 seconds	8 Cal. 50	265 rds/gun
P-38	40.8 seconds 15	4 Cal. 50 1 20 mm	500 rds/gun 150 rds/gun
P-51 D	40.8 seconds	4 Cal. 50	500 rds/gun

A fighter armed with guns, bombs, and rockets has a tremendous destructive power. Because of this, very strict safety precautions are necessary if accidents are to be prevented. Keep all armament switches OFF until you are ready to fire. Check the operation of all firing circuits, including the camera, before any ammunition, rockets, or bombs are loaded. If a gun jams or a rocket fails on a mission, call an armorer as soon as you land.

PREFLIGHT INSPECTION

1. Ammunition should be loaded smoothly and evenly in boxes. All link and cartridge chutes should be connected.
2. Gun mounts and solenoids should be secure.
3. Dzus fasteners should be in good condition, and ammunition box covers and gun-bay doors should be fastened securely.

CONTINUOUS FIRING LIMITS

The following table indicates maximum bursts which can be fired in cal. .50 M2 machine guns without danger of cook-off.

Initial Burst Rounds	Secondary Burst Rounds	Cooling Interval Between Bursts (seconds)	Maximum number of Secondary Bursts which can be fired without danger of cook-off
10	10	30	21
15	15	30	10
15	15	60	14
25	25	60	6
50	50	30	2
50	50	60	2
75	20	60	5
75	15	60	10
75	10	60	40
100*	—	—	—
150*	—	—	none

*150 rounds is the maximum single burst which can be fired without danger of cook-off. Therefore, only one 100-round burst can be fired without the same danger.

Frequent inspections should be made and, if possible, the gun barrels should be changed after firing 1500 rounds.

LOADING

Insert the double loop end of ammunition belt through the feeding belt until the first cartridge is beyond the belt-holding pawl. Close the cover and charge the gun twice.

UNLOADING

Lift cover, remove belt, retract bolt, and make a visual inspection of the feedway T-slot and chamber, to make sure the gun is not loaded.

Release the bolt and lower the cover.

Press trigger or sear mechanism to relieve the tension on the firing pin spring.

GUN JAMS

A few of the more common causes of gun jams are: faulty ammunition, failure of personnel to inspect the gun, excessive wear in the feeding or extracting mechanism, broken T-slot, or broken barrel extension.

CARE

The kind of care given this weapon largely determines whether or not it will shoot accurately. Clean the bore thoroughly with rifle bore cleaner. Use lubricating, preservative, special, oil U. S. Specification 2-120 or AXS 777 for all parts of the weapon. Apply oil lightly. Proper functioning is now assured to minus 65° F.

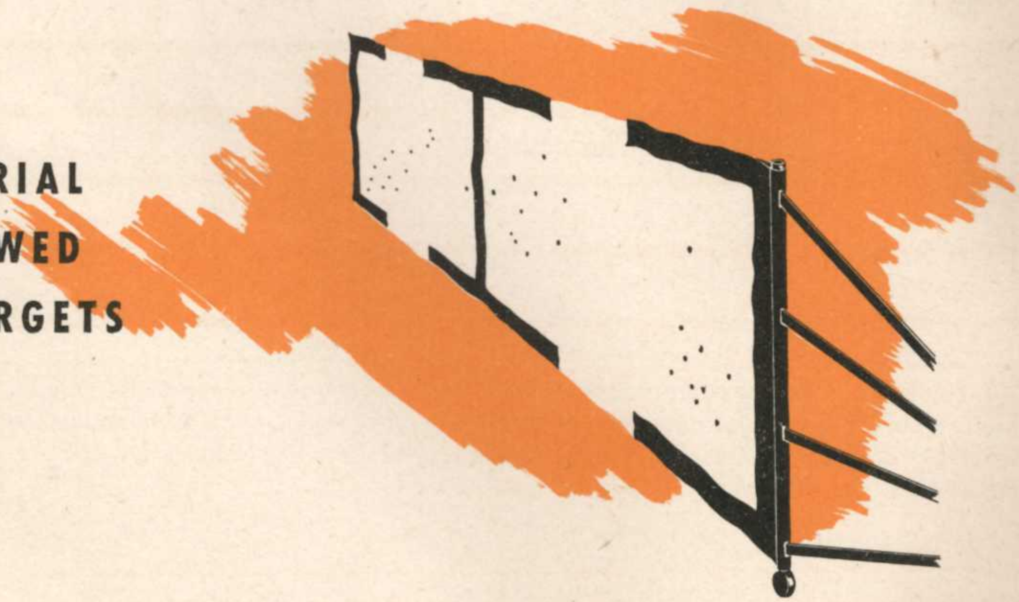
If the guns remain mounted in the airplane, cover all exposed parts to protect them from the weather.

AMMUNITION

Specific information on the guns and ammunition for fighter airplanes can be found in the following technical orders or manuals.

SUBJECT	REFERENCE
Machine Gun, Cal. .30, M2 Aircraft	T. O. 11-1-47
Browning Machine Gun, Cal. .50 M2 Aircraft, Basic	TM 9-225
Cal. .50 Aircraft Machine Gun M2	T. O. 11-1-8
20 mm Aircraft Automatic Gun AN-M-2	T. O. 11-1-16
20 mm Aircraft Automatic Gun AN-M-2	TM 9-227
37 mm Automatic Gun M-4	T. O. 11-1-52
37 mm Automatic Gun M-4	TM 9-240
37 mm Automatic Gun M-9	TM 9-241

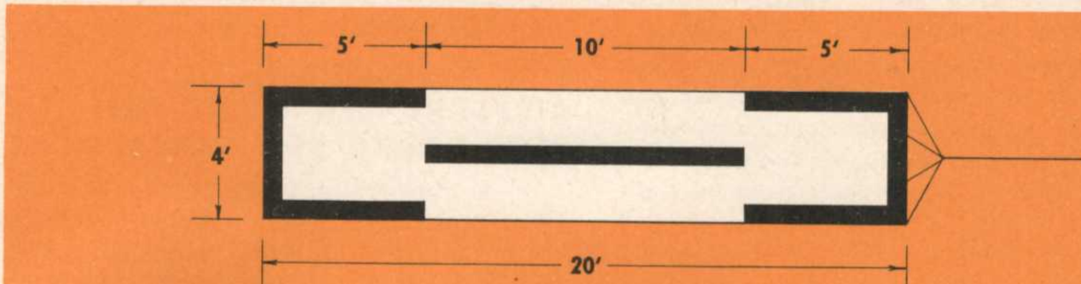
AERIAL TOWED TARGETS



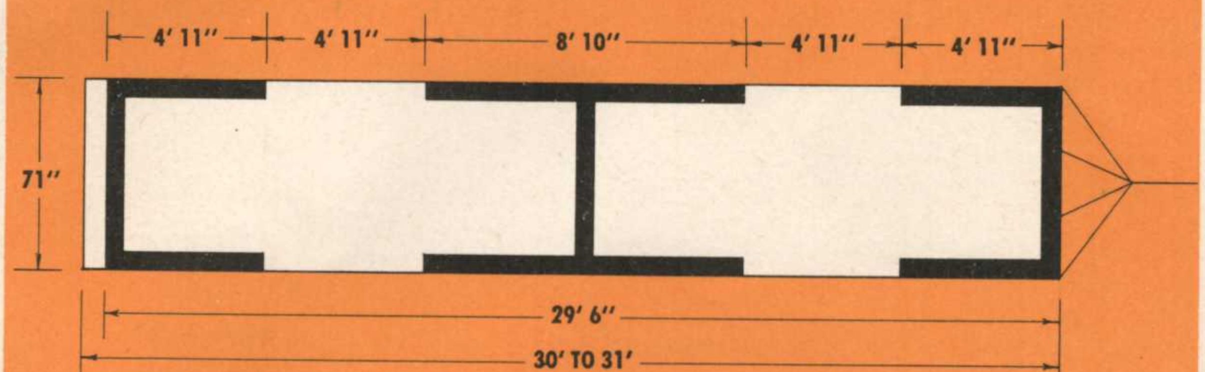
The A-6-A (6 ft. by 30 ft.) and A-10 (4 ft. by 20 ft.) are the standard towed targets. They are made of cloth wound wire, 3/32 inch mesh. Painted ammunition leaves color-rimmed holes for scoring. After each mission, cancel the holes with a stenciling brush and score the hits in their approximate position on a target score sheet—a small replica of the target.

TARGET MARKINGS:

It has been determined by numerous tests that marking the A-6-A and A-10 targets with black paint to the illustrated dimensions results in a number of benefits. The assessability of gun camera film exposed on target firing missions usually increases by 30% to 40%. Accuracy of assessment increases since the tar-



A-10 TARGET



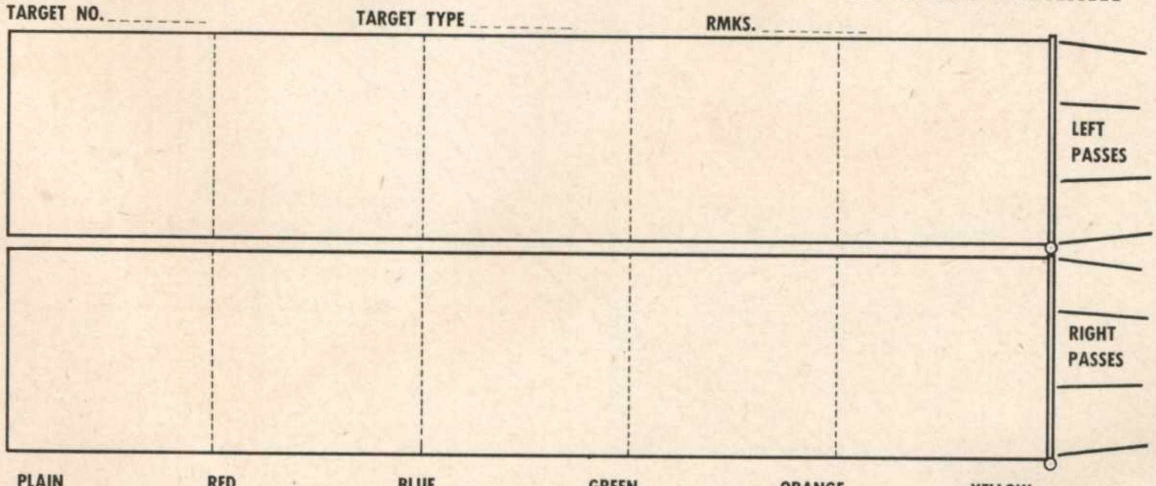
A-6A TARGET

AERIAL GUNNERY SCORE SHEET

DATE ____________ SQDN. ____________ TOW PLANE ____________ ALT. ____________________ FT. ______

MISSION ________________ PILOT __________________ T.A.S. ______________________________ M.P.H. _______

TARGET NO. ________ TARGET TYPE ________ RMKS. _________

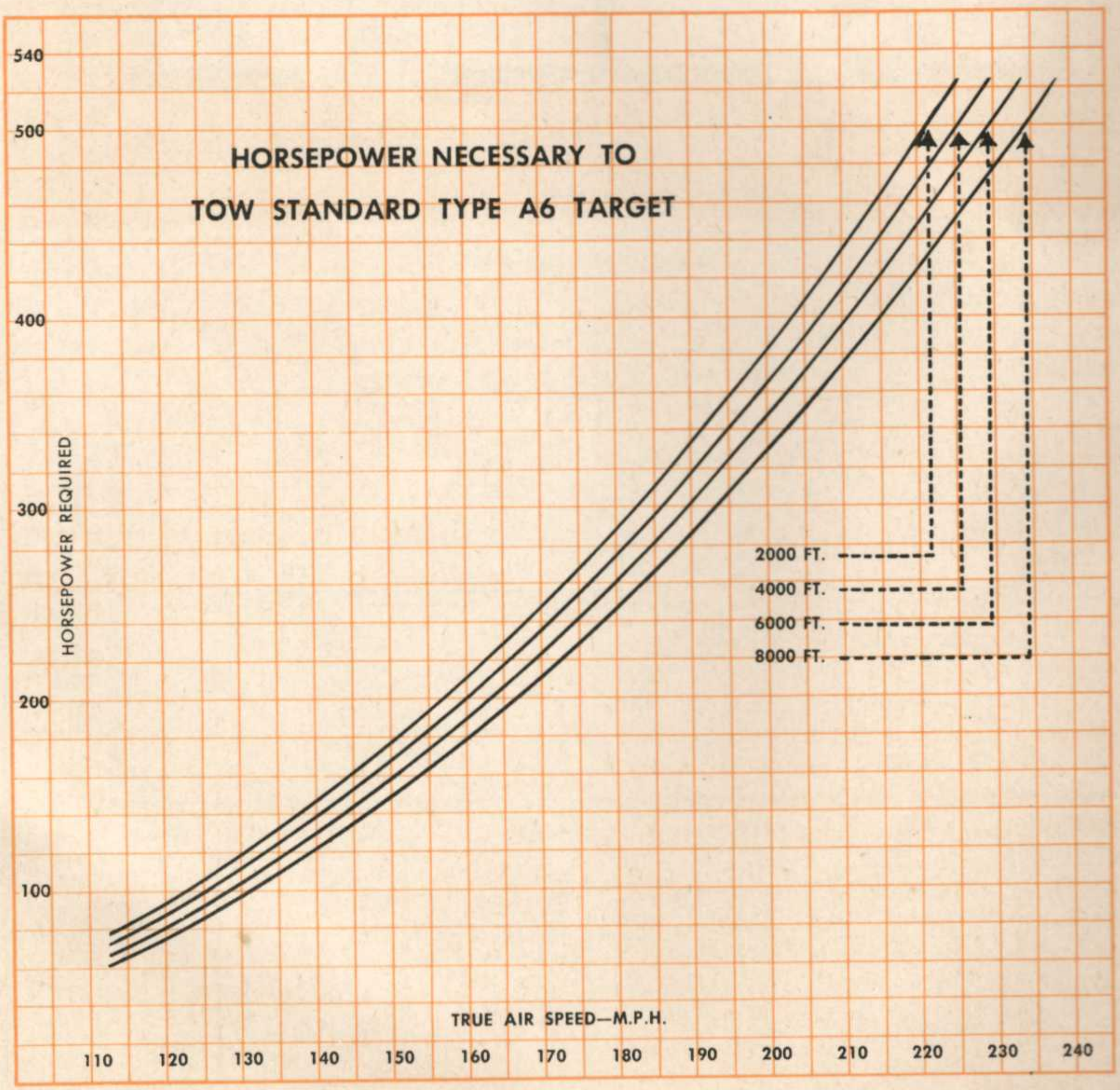


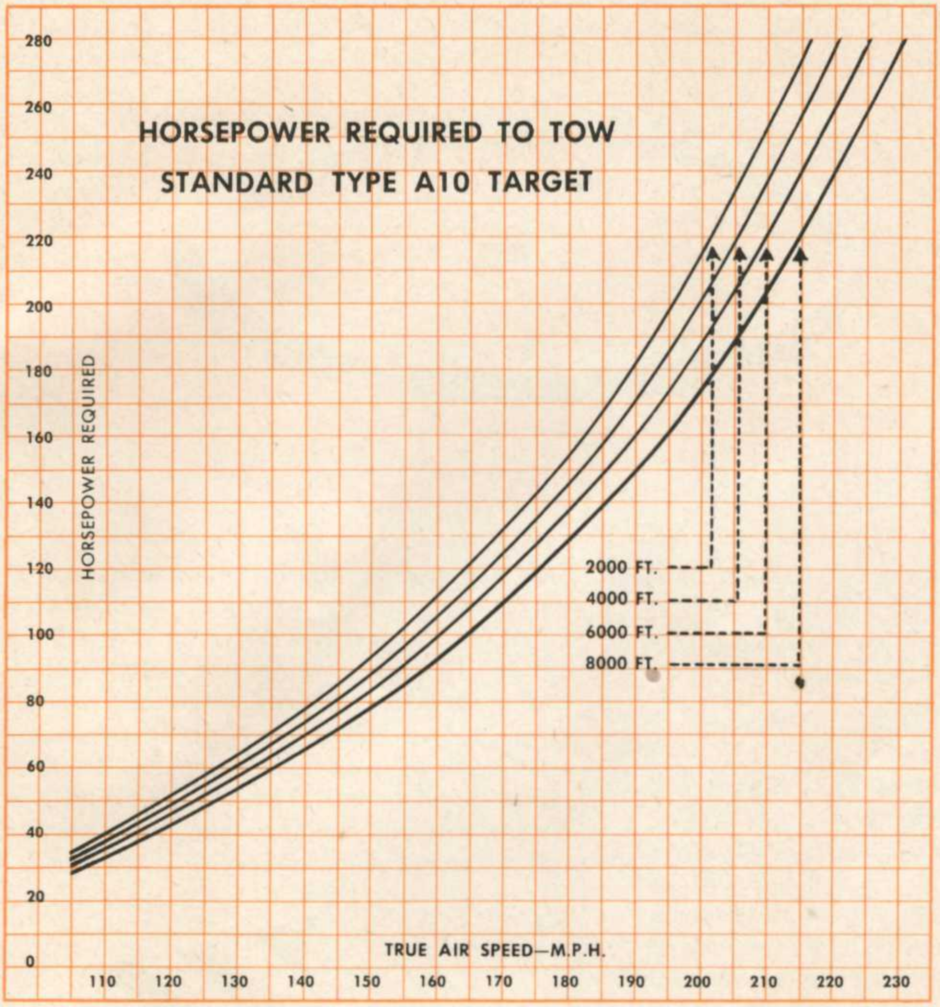
PLAIN	RED	BLUE	GREEN	ORANGE	YELLOW
LEFT ________	LEFT ________	LEFT ________	LEFT ________	LEFT ________	LEFT ________
RIGHT ________	RIGHT ________	RIGHT ________	RIGHT ________	RIGHT ________	RIGHT ________
TOTAL ________	TOTAL ________	TOTAL ________	TOTAL ________	TOTAL ________	TOTAL ________
1L _____ 1R _____	1L _____ 1R _____	1L _____ 1R _____	1L _____ 1R _____	1L _____ 1R _____	1L _____ 1R _____
2L _____ 2R _____	2L _____ 2R _____	2L _____ 2R _____	2L _____ 2R _____	2L _____ 2R _____	2L _____ 2R _____
3L _____ 3R _____	3L _____ 3R _____	3L _____ 3R _____	3L _____ 3R _____	3L _____ 3R _____	3L _____ 3R _____
PILOT PLANE ________	PILOT PLANE ________	PILOT PLANE ________	PILOT PLANE ________	PILOT PLANE ________	PILOT PLANE ________

gets are more clearly defined. When targets so marked are used with the target assessment models included with the W-2 Exact Assessor Kit, accurate assessments can be made even though a portion of the target is torn off. These markings are placed on the target so that definite ratios of target length to width are established, thus giving correct angle off readings during assessment. In normal usage the 6 ft. by 30 ft. (A-6-A) target varies from 27 ft. to 31 ft. in length, the variation being between a new target of 30 plus feet and a used target that has lost several feet of the trailing edge after several towing missions.

AIRPLANE POWER AND FUEL REQUIRED TO TOW TARGETS

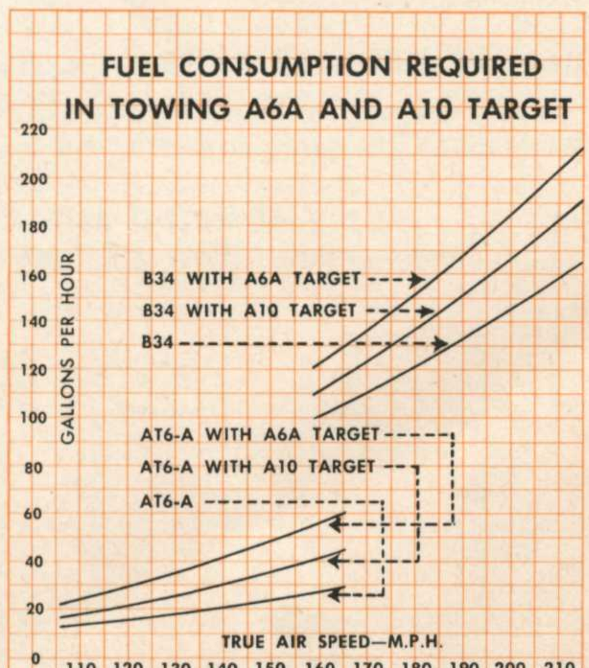
It requires 410 hp to tow an A-6-A target at 200 mph true airspeed at 2000 ft. altitude; 210 hp to tow the A-10 target under similar conditions. THIS DOES NOT INCLUDE THE HP NECESSARY TO FLY THE AIRPLANE AT THIS SPEED. The first two graphs show hp necessary to tow targets at various airspeeds and altitudes.



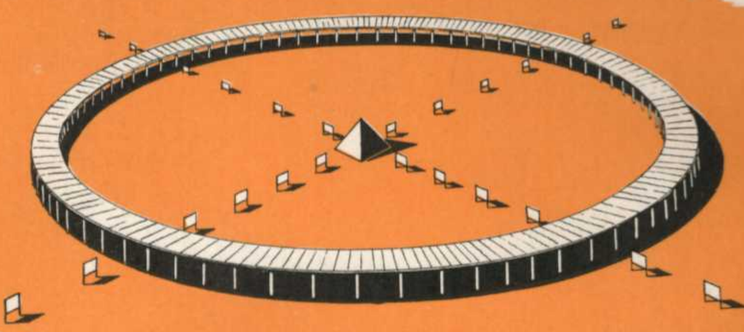


This third graph shows the fuel consumption required to tow the targets at various true airspeeds. For example, notice that the B-34 burns 41 more gallons per hour at maximum economy fuel setting when it is towing an A-6-A target at 200 mph true airspeed than when it is flying at this same speed with no target.

These three graphs indicate that high speed and high altitude towing (above 20,000 ft.) is impracticable with the present high-drag targets.



RANGES



AERIAL RANGES

An aerial gunnery range is nothing more than the airspace above a clearly-marked uninhabited area. It should be established as a danger area. Recommended lengths for aerial gunnery ranges are:

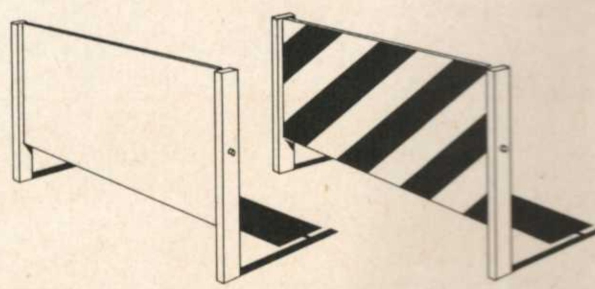
Length Miles	Indicated Tow Speed	Altitude in Ft.
10	150	0-20,000
15	200	0-20,000
20	150	20,000 - up
25	200	20,000 - up

Ranges should be identified by numbers or definite land marks. Tow airplanes can stack up at different altitudes on the same range.

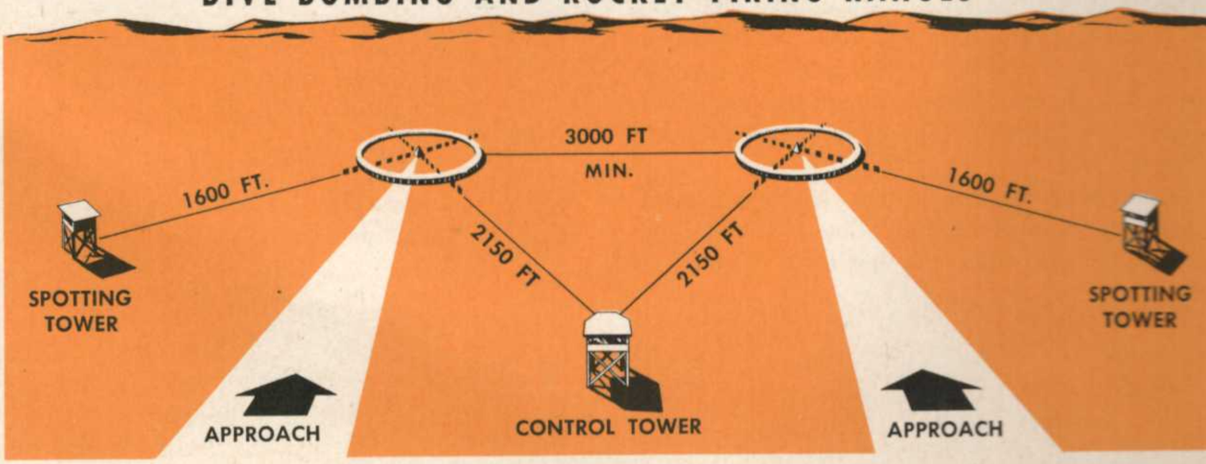
GROUND GUNNERY RANGES

An air-to-ground gunnery range usually consists of six to eight C-type rifle targets. They are six ft. by ten ft., have a scoring area six ft. by six ft., and a three ft. bullseye. The target is inclined at a 60° angle from horizontal. Other range equipment includes a protective house for the range crew, and a range panel (striped on one side, white on the other).

The use of each range depends on local safety requirements. This target can be used for low altitude strafing, wing line strafing, and normal ground gunnery.



DIVE BOMBING AND ROCKET FIRING RANGES



This sample range consists of two targets, two spotting towers, and one control tower. The bullseye is a wooden pyramid surrounded by a 150 ft. diameter circle. The circle is made of a board lattice three ft. wide and three ft. above the ground. The color of the circle and bullseye should contrast the surrounding ground. Alternate white and black lattice is suggested.

Each target has two lines of numbered stakes at 15 ft. intervals crossing through the center of the circle; one line is perpendicular to the nearest spotting tower, the other perpendicular to the control tower. These stakes help the tower observers score hits.

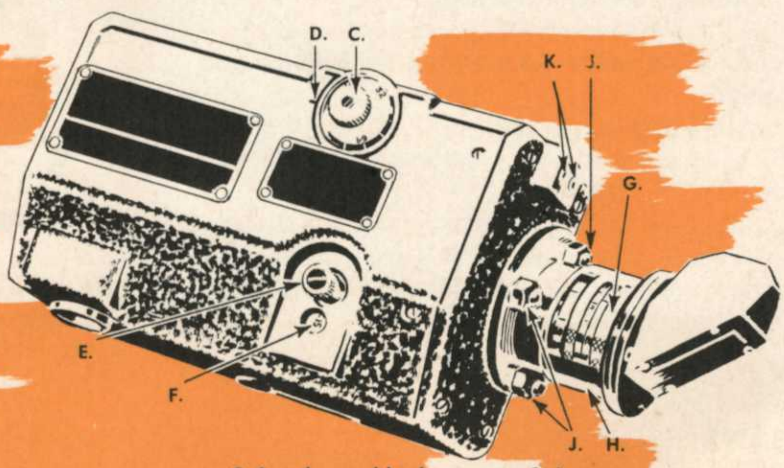
A 30 ft. control tower and 20 ft. spotting towers are suggested. Necessary equipment includes wide vision binoculars or an alidade to read bomb impact, plotting boards, telephone connections between towers, and a TWO-WAY RADIO IN THE CONTROL TOWER to instruct and control traffic. Devices for measuring the pilot's dive angle, slant range, and hits should be included in the range equipment. These instruments are used during the pilot's preliminary training to coach him on dive angles and range estimation. Typical instruments are a Harp and Navy Position Angle Finder, Mk-1 Mod 1. Binoculars with mil graduations can be employed for spotting purposes.

Each pilot should call his number on the radio as he rolls into a dive, enabling the spotters to check the area and score hits. The man in the spotting tower telephones his impact reading to the control tower where the hits are plotted.

RANGE OPERATION

The flight is instructed and controlled from the control tower. It is coached on dive angles and slant range by use of the devices previously mentioned, especially during preliminary training. A flight of 4 planes is considered optimum and is led by an instructor. Patterns should be set in accordance with local safety regulations. Each pilot calls his number on the radio just before entering a dive. This enables the control tower operator to coordinate the slant range, dive angle, and hit with the proper airplane. Measurement of the impact is phoned to the control tower from the spotting tower and the hit is scored on the plotting board.

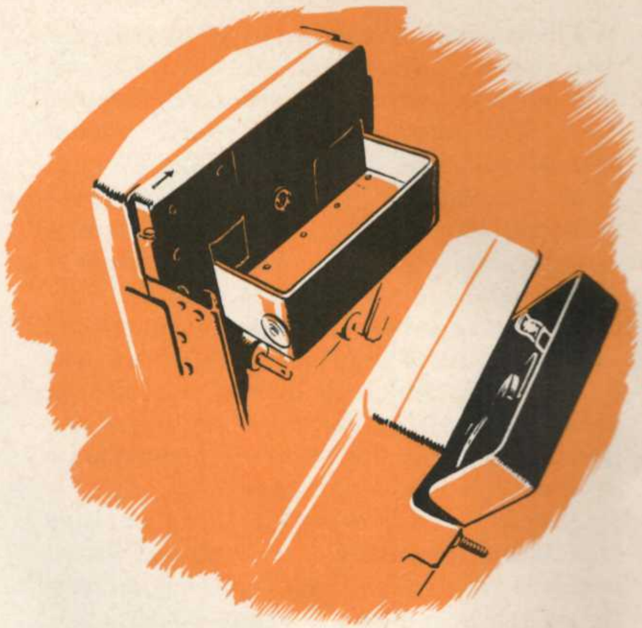
GUN CAMERAS FILM AND FILM PROCESSING



C. Speed control knob
D. Speed index mark
E. Footage indicator knob
F. Footage dial
G. Lens
H. Lens sheath
J. Lens mounting studs
K. Lens heater pin jacks

The AN (Army Navy Standard) gun camera is a motion picture camera used to record results in aerial gunnery, rocket firing and bombing. It is installed in the fighter's wing or nose and, when properly harmonized, records the action during the firing period. It may be used alone ("Camera Exercises") or in conjunction with the guns, rockets or bombs. Errors in pilot technique are shown by projecting and analyzing the film.

Both the Bell and Howell Company and the Fairchild Aviation Corporation manufacture these cameras. The two cameras are practically the same size, approximately 6 in. by $3\frac{1}{2}$ in. by $2\frac{1}{2}$ in. Although they are similar in appearance, only the lens assemblies are interchangeable. An outstanding difference in the two is the door. The Fairchild product has a button on each side that must be slid forward to open the door. Then, a lever must be pulled down to load or unload and pulled up again before the door will close. This meshes the camera drive gear with that of the film pack. The Bell and Howell camera has a snap lock arrangement.



TYPES AND DESIGNATIONS

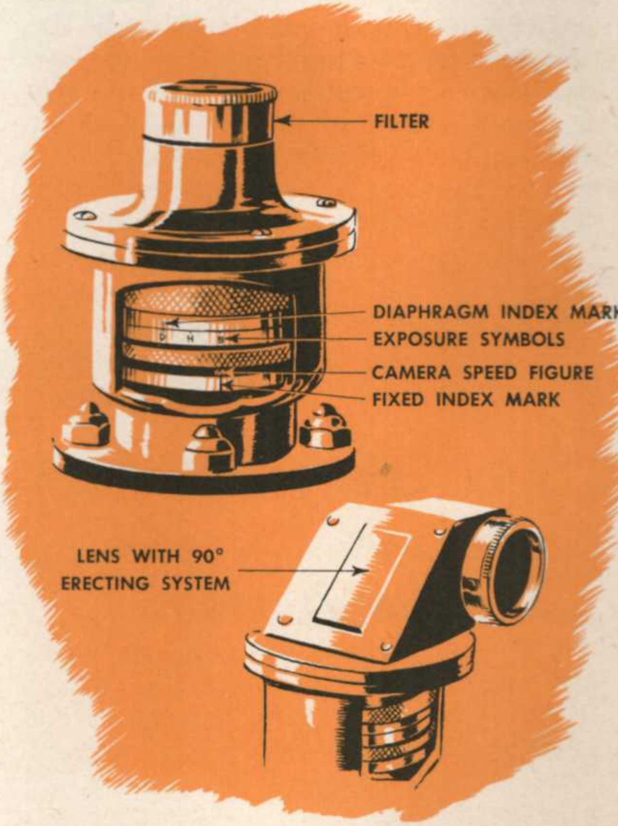
The camera is manufactured in both 12 or 24 volt models. A four pole receptacle supplies the power. The No. 1 pin is the common ground, No. 2 leads to the motor, No. 3 to the heater, No. 4 to the overrun indicator solenoid. The No. 3 pin is enlarged to provide positive polarization. The letter M designates the 12 volt camera and the letter N identifies the 24 volt model. The number following the letter designates the lens assembly:

1. 3 inch lens—f 4.5
2. 3 inch lens—f 4.5 with a 90° erector assembly
3. 35 mm lens—f 3.5
4. 35 mm lens—f 3.5 with a 90° erector assembly

The camera type depends on the lens assembly. An M-1 becomes an M-4 when the 3-inch lens is replaced with a 35 mm lens f 3.5, using a 90° erector assembly.

LENS

All the lens assemblies on current gun cameras are interchangeable. Three easily-removed nuts fasten the lens to the camera body. The lens unit consists of two marker rings. One ring, marked 16, 32, 64, corresponds to the camera speeds of 16, 32, and 64 frames per second. The lower ring controls the lens diaphragm.



To make a correct lens setting, set the marker ring with the camera speed of 16, 32, or 64 frames per second. Then set the diaphragm ring at B, H, or D, depending on the lighting condition and exposure desired.

GUN CAMERA LENS SETTINGS

Frames per second.	Corresponding f number		
	Bright	Hazy	Dull
64	f 8	f 5.6	f 4.5
32	f 11	f 8	f 5.6
16	f 16	f 11	f 8

Notice the error that results if the camera is set at one speed and the lens at another: if the camera speed is changed from 16 frames per second to 32 frames per second and the lens marker ring is left at 16 D (f 8), the lens setting becomes equivalent to 32 H. This prevents the proper amount of light from reaching the film.

All lenses are equipped with a minus blue filter that absorbs blue light. This filter cuts through haze, darkens the sky, and protects the lens from dirt and oil. It does not make an aerial target appear more clearly in the picture since there is relatively little haze between you and the target. It makes the background appear more clearly. Replacing this filter with clear optical glass builds up the effect of the background haze and makes the target stand out more distinctly.

The 3-inch records a field of view 5.5° by 8° or 98.1 mils by 139 mils. The 35 mm lens records 12° by 17° or 212.8 mils by 300.9 mils. These figures are based on the aperture size (.410 by .289 inches) of the A-6 film magazine.

GLASS ENCLOSURES

Good camera results are possible only if all glass through which light passes to reach the film is clean. In some installations, the glass alone absorbs as much as 65% of the light: **Keep all canopy and camera windows clean!**

SPEEDS

Gun cameras have three operating speeds: 16, 32, and 64 frames per second. Change the speed by moving the external speed control knob on top of the camera. The camera does not operate on intermediate settings; 24 frames per second cannot be obtained by setting the dial midway between 16 and 32.

CAUTION: **Do not change the camera speed while it is operating as this will strip the driving gears.**

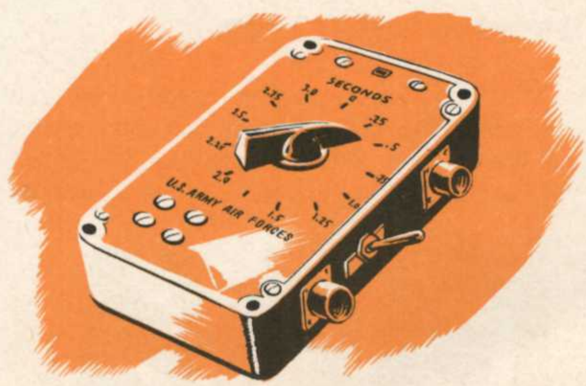
The rate at which the film travels through the camera is not exactly the same as indicated. Tests of cameras set at 64 frames per second ran from 52 to 76.6 frames per second; set at 32, ran from 28.6 to 37.5; set at 16, ran from 14.9 to 19.4 frames. The camera requires about .194 seconds to get to its operating speed. Do not use the first three or four frames for assessing because the pictures may be distorted.

HEATERS

Built-in, thermostatically regulated heating units maintain temperatures inside the camera between 45° and 90° F. The camera body also has an electrical outlet on the front plate for attaching a filter heater. Camera failure at high altitudes may result if the thermostat sticks, thereby burning out the camera.

OVERRUN CONTROLS

Overrun control units come in both the 12 and 24 volt models. They are manufactured by the two camera companies and appear the same in size and mounting dimension, but their parts are not interchangeable.



This control keeps the camera in operation long enough to record the effect of the last bullet. The overrun control is a separate unit and must be set to the desired time of overrun. The maximum time is three seconds graduated in .25 second intervals. Set the desired time on the calibrated dial on the outside of the control.

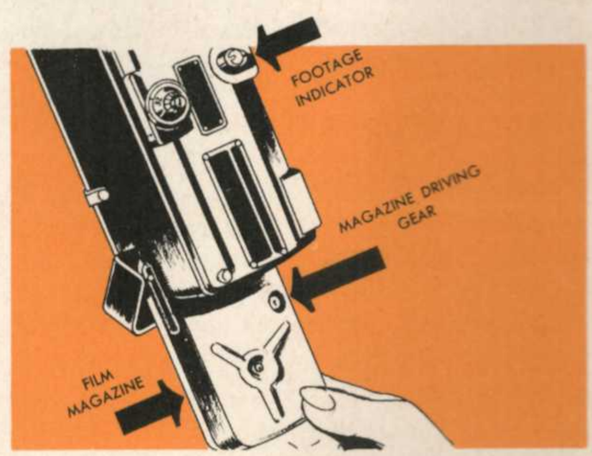
OVERRUN FRAMES AND FEET OF FILM EXPOSED AT VARIOUS TIME SETTINGS

Overrun settings (seconds)	16		32		64	
	Frames	Feet	Frames	Feet	Frames	Feet
.25	4	.1	8	.2	16	.4
.50	8	.2	16	.4	32	.8
.75	12	.3	24	.6	48	1.2
1.00	16	.4	32	.8	64	1.6
2.00	32	.8	64	1.6	128	3.2
3.00	48	1.2	96	2.4	192	4.8

The Fairchild Aviation Corporation makes a camera (N-6) incorporating an overrun that can be set at two seconds or zero. Newer models have a 0 to 5 seconds variable setting adjustment. Adjustments are made by taking off the top cover and turning the set screw. Do not connect an external overrun control without first disconnecting the built-in unit.

OVERRUN INDICATOR

A solenoid in the camera actuates a small pin extending into a corner of the camera aperture. This pin, the overrun indicator, causes a shadow of itself to be registered on the film when the camera is coasting or operating on the overrun. When you squeeze the gun trigger, the pin withdraws from the aperture and does not register on the film. When viewing the film, you can decide which frames correspond to actual firing and which are a result of the overrun.



FILM MAGAZINE

Current gun cameras use the standard A-6 magazine. It is a stamped metal cartridge, approximately 5 in. by 3 in. by ¾ in., and can be loaded with lengths of film up to 50 ft.

FIRING TIME WITH VARIOUS SPEED SETTINGS (50 ft. of film)

Speed Setting	Seconds
64	31
32	62
16	125

The film is exposed through the large aperture in front of the magazine. It is engaged and pulled through the camera by (1) a large tooth in the camera that engages the perforations through the small aperture in the front, and (2) the gear on the side opposite the footage indicator that meshes with a gear in the camera. The magazine is a delicate piece of equipment, so handle it carefully. An improperly aligned or dented magazine will jam. DO NOT FORCE THE FILM PACK INTO THE CAMERA.

To check for a jam, examine the perforations visible in the small aperture. If they are torn, the magazine is jammed. Get a new magazine. To check film movement, make a mark on the film through the large aperture. If the mark is still there after you operate the camera, either the magazine or camera is defective. Check the magazine for dents, loose masking tape, and damage to the driving gear.

LOADING

Insert the magazine so its drive gear is adjacent to the camera footage indicator. Lock the door tightly, or the film invariably will jam.

PRECAUTIONS

1. Do not run the camera unless the door is securely closed.
2. When loading, do not jar the camera out of alignment.
3. If developed pictures indicate the camera is out of alignment or has a bad shutter, have it repaired.
4. Do not change the camera speed if the camera is running. This strips the drive gears.

TITLING THE FILM

Title your film prior to each mission. Make a short exposure of your name, squadron, type of fighter, and any other pertinent or desired information.

PILOT'S GUN CAMERA CHECK LIST

1. Camera operation: camera should operate through the firing circuit.

2. Light setting: set at expected lighting conditions.

3. Speed: the lens diaphragm speed must correspond to the camera speed.

4. Glass enclosures: all filters, protective glass and canopies through which pictures are taken must be free from oil, dirt and obstructions.

5. If the camera is accessible from the cockpit, the footage indicator should correspond with the remaining film in the magazine.

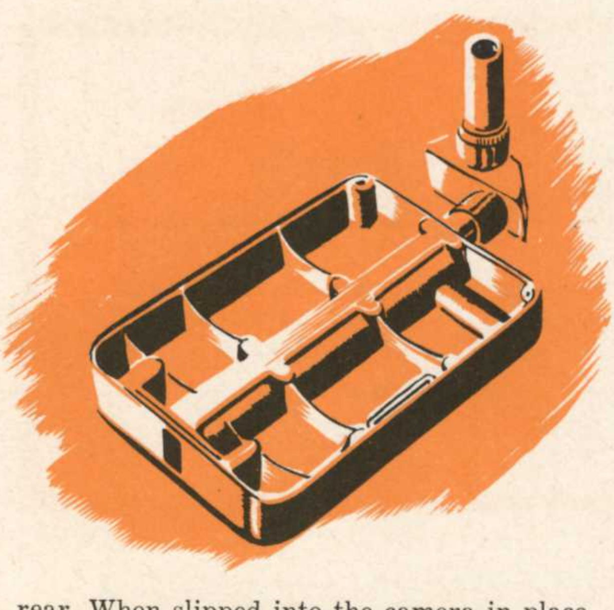
MOUNTING

All fighters have mounts and wiring for the AN gun camera. Although the camera was originally intended to be mounted behind the gunsight, the visibility obstruction and added crash hazard have resulted in wing or nose installations.

HARMONIZING THE GUN CAMERA

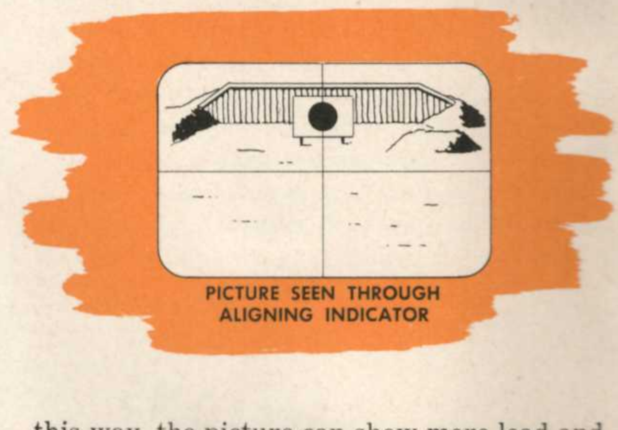
Harmonize the camera so it includes the area covered by the bullets. The lens coverage is small and requires precise harmonization to include high deflection targets. If the camera photographs through the gunsight, adjust it so it aims at the ring and pipper.

Align the camera with the boresight tool or aligning indicator. This device, shaped like a film magazine, has a viewing telescope at the



rear. When slipped into the camera in place of the magazine, cross-hairs in the indicator show the camera's aiming point. Align this with the gunsight the same way you harmonize the guns. The camera shutter must be open. Open it by turning the speed change knob or by momentarily operating the camera. Adjustments provided in the camera mount may consist of a universal joint, a screw adjustment, or slotted holes for azimuth and elevation. To align some camera installations, it is necessary to use shims or washers.

The intersection of imaginary lines joining the fudicial marks appearing in the projected picture indicate the center of the picture. This center point is not always used as the aiming point. A point in the center upper half of the frame is more desirable, for the target image usually is in the lower part of the frame. In



PICTURE SEEN THROUGH ALIGNING INDICATOR

this way, the picture can show more lead and still have the entire target in the frame. SINCE THE CENTER OF THE PROJECTED PICTURE DOES NOT COINCIDE WITH THE SIGHT LINE, YOU MUST TAKE A CAMERA SIGHTER BURST. At the beginning and end of each film pack, fire the camera with the sight pipper exactly on an easily recognized object at 2000 ft. minimum range. Use this reference aiming point to reconstruct a sight ring when assessing the film. CAUTION: Be sure the gun switch is on "Camera" and be careful when selecting the object.

TIPS

1. Check camera harmonization frequently. Keep all clamps and locks tight.

2. If the window frame cuts off part of the picture, shim the entire mount a small distance.

3. Protect the camera and camera window from damage. When camera is not in use, cover it with a protective envelope or bag and the window with heavy paper and masking tape.

Do not drag fuel hoses across the camera window.

4. Clean the window carefully to avoid scratching.

5. To help correct blurring caused by vibration, use a higher shutter speed.

6. If mount vibration loosens camera screws or nuts, tighten and shellac them in place.

PROCESSING THE FILM

Negative processing is considerably simpler than reversal processing and is equally satisfactory for assessing purposes. Reversal processing has a psychological advantage in that it more closely resembles the original scene, thereby aiding memory. The advantageous results of negative processing are a gain in speed and a decreased necessity for precise exposing and developing. The quality of the negative is affected by five factors:

1. The light on the subject
2. Film speed
3. Camera speed
4. Camera aperture or lens setting
5. Speed of processing

Although previous information in this section requires a change in lens settings for various light conditions, excellent results can be obtained with negative processing by setting the shutter speed and aperture openings at a permanent position and varying the processing time to suit the light conditions encountered upon exposure of the film.

Recommended settings for cameras using Cine Super X film at 32 frames per second with a minus blue filter:

INSTALLATION	SETTING
Wing or nose camera (unobstructed)	32 H
P-47 cockpit camera (bulletproof glass)	32 wide open

NOTE: These settings were computed at 28° North Latitude. An extreme difference in latitude might require adjustment of the exposure scale.

For film exposed as suggested in the above table, this schedule of developing speed is recommended:

WEATHER	DEVELOPER MACHINE SPEED
Bright	15-16 feet per minute
Cloudy	13 feet per minute
Dull	10 feet per minute

NOTE: As the developer ages from use or exposure to the air, the required processing rate decreases one to two feet per minute.

CONVERTING THE DEVELOPING MACHINE TO THE NEGATIVE PROCESS

The following changes are required to convert the K-1A developing machine to negative processing:

1. Disconnect pump.

2. Plug manifold—openings to rear and closest to top of tanks No. 2 and No. 6.

3. Disconnect printing lights and tape up red window so compartments No. 1 and No. 2 are light tight.

4. Fill tanks as follows:

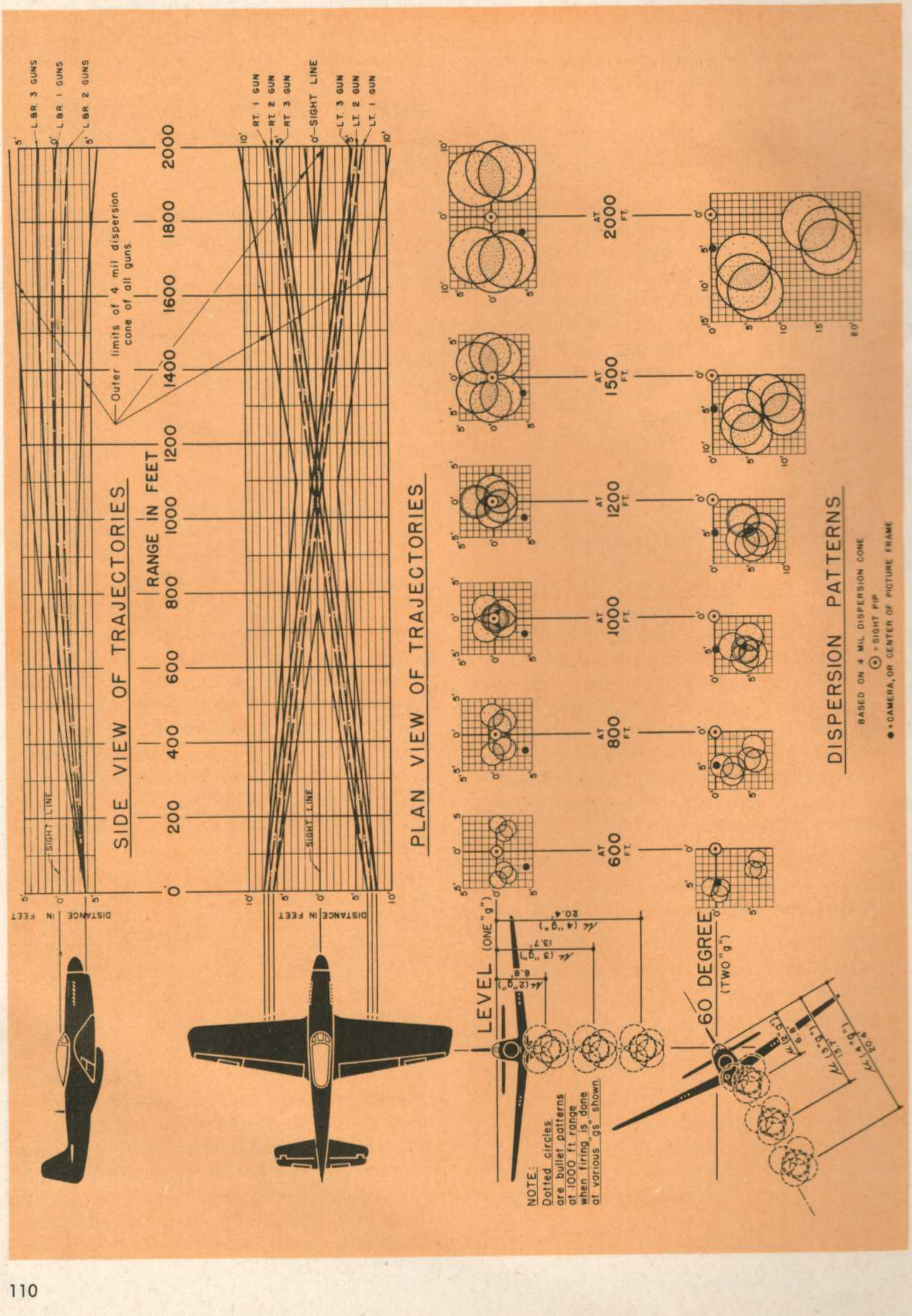
TANK	SOLUTION
1	Dry
2, 3, 4, 5	Developer, type D
6	Water, change daily
7, 8	Fixing bath, F-7
9	Wash Water
10	Glycerine and aersol rinse

Type D developing powders, AAF specification No. 31215, are available in one gallon and four and one-half gallon cans. Each change requires three large cans. Use the one gallon size to prepare replenishing solution. The formula is in T. O. 10-5-7. Change the water in tank No. 6 daily to prevent accumulation of alkali and antihalation dye.

Use this formula to prepare the Kodak F-7 Fixing bath:

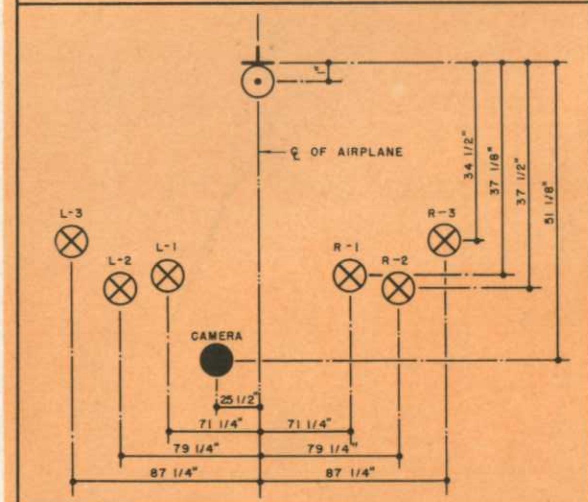
Water	4½ gal.
Sodium Thiosulfate (hypo)	18 lbs.
Ammonium Chloride	2½ lbs.
Sodium Sulphite	12 oz.
Acetic Acid Crystals	36 oz. (fluid)
Boric Acid Crystals	6 oz.
Potassium Alum	12 oz.
Water	6 gal.

Prepare the glycerine and aersol rinse according to T.O. 10-25-15. Maintain the developer level in the tanks by adding fresh solution. One change of chemicals can process approximately 12,000 feet of film. After eight days, oxidation weakens the developer enough to require a change even though the prescribed film footage has been processed.


SIDE VIEW OF TRAJECTORIES
RANGE IN FEET
0
200
400
600
800
1000
1200
1400
1600
1800
2000
DISTANCE IN FEET
SIGHT LINE
L.BR. 3 GUNS
L.BR. 1 GUNS
L.BR. 2 GUNS
Outer limits of 4 mil dispersion cone of all guns.
PLAN VIEW OF TRAJECTORIES
RT. 1 GUN
RT. 2 GUN
RT. 3 GUN
0'–SIGHT LINE
LT. 3 GUN
LT. 2 GUN
LT. 1 GUN
LEVEL (ONE "g")
60 DEGREE (TWO "g")
NOTE: Dotted circles are bullet patterns at 1000 ft. range when firing is done at various "gs" shown.
6.8' (2 "g")
13.7' (3 "g")
20.4' (4 "g")
AT 600 FT.
AT 800 FT.
AT 1000 FT.
AT 1200 FT.
AT 1500 FT.
AT 2000 FT.
DISPERSION PATTERNS
BASED ON 4 MIL DISPERSION CONE
⊙ = SIGHT PIP
● = CAMERA, OR CENTER OF PICTURE FRAME

HARMONIZATION CHART P-51D

1000 INCH BORESIGHT TARGET



TARGETS SHOWN ARE FOR HARMONIZATION UNDER THE FOLLOWING CONDITIONS: (BASIC HARMONIZATION)

CAL. I.A.S. = 300 M.P.H.
ALTITUDE = 15,000 FT.
T.A.S. = ±373 M.P.H.
WEIGHT = 9,500 LBS. ± 200 LBS.
ANGLE OF ATTACK (∝p) = 13 MILS NOSE UP
LEVEL FLIGHT (1"g")

+ = MARK WHERE LINE FROM SIGHT IS PARALLEL TO FUSELAGE LEVELING LUGS.

⊙ = MARK WHERE SIGHT PIP IS AIMED FOR HARMONIZATION WITH BULLET PATTERNS. (SIGHT SETTING FOR THIS HARMONIZATION.)

⊗ = MARK WHERE BORE IS AIMED FOR 1000 INCH AND 500 FOOT TARGETS.

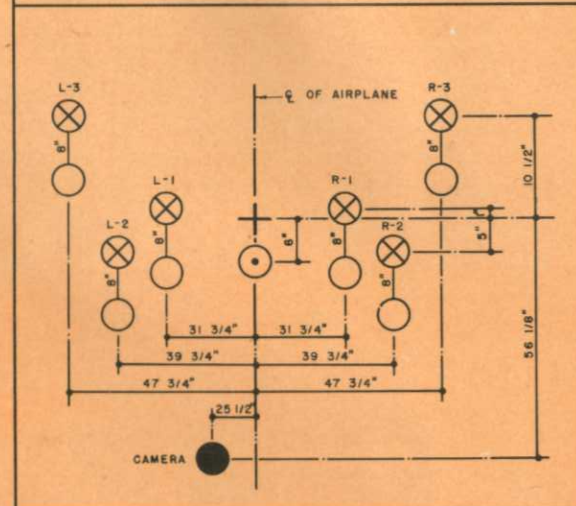
○ = MARK FOR CENTER OF IMPACT OF 10 ROUNDS AT 500 FT. TARGET.

● = MARK WHERE CAMERA IS AIMED MAKING CAMERA PARALLEL TO SIGHT LINE. THIS POINT REPRESENTS THE CENTER OF THE PICTURE FRAME.

GUN LOCATION AT AIRCRAFT

CALIBER 0.50	VERT. (FROM SIGHT)	HORIZ. (FROM PLANE ℄)
L.& R. NO. 1 GUNS	44.732"	79.123"
L.& R. NO. 2 GUNS	44.002"	87.091"
L.& R. NO. 3 GUNS	43.493"	95.076"
CAMERA	50.140"	25.561"

500 FT. FIRE-IN & BORESIGHT TARGET



FLIGHT ANGLE	ALT.	CAL. IAS	± TAS	MIL ANGLE "μ" 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	0'	250	250	+1.0	+8.1	+15.0	+22.1
		300	300	—0.6	+5.0	+10.8	+16.4
		350	350	—1.9	+2.9	+7.5	+12.3
		400	400	—3.1	+1.1	+5.1	+9.2
		450	450	—3.9	—0.4	+3.2	+6.7
LEVEL FLIGHT	7000'	200	222	+4.1	+14.0	+23.8	—
		250	276	+1.5	+9.1	+16.7	+24.4
		300	331	—0.3	+5.8	+12.0	+18.1
		350	386	—1.8	+3.4	+8.5	+13.7
		400	440	—3.1	+1.5	+5.8	+10.2
LEVEL FLIGHT	15000'	200	251	+5.0	+16.1	+27.0	—
		250	313	+2.0	+10.6	+19.0	+27.6
		300	373	0	+6.8	+13.7	+20.4
		350	434	—1.6	+4.1	+9.5	+15.4
		400	493	—3.1	+2.0	+6.6	+11.5
LEVEL FLIGHT	30000'	150	242	+13.0	+31.8	—	—
		200	320	+7.0	+20.6	+34.1	—
		250	398	+3.3	+13.7	+24.1	+34.5
		300	471	+0.8	+8.9	+17.3	+25.4
		350	543	—1.3	+5.6	+12.2	+19.0

FLIGHT ANGLE	CAL. IAS	∝p. (WT. = 9500 LBS.) 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	150	+134	+296	—	—
	200	+63	+155	+246	—
	250	+30	+89	+147	+206
	300	+13	+53	+94	+134
	350	+2	+32	+61	+91
	400	—6	+18	+40	+63
	450	—10	+8	+26	+44

∝p = MIL ANGLE BETWEEN THE FUSELAGE LEVELING LUGS AND THE FLIGHT PATH. THIS DATA IS DERIVED FROM THE BEST AVAILABLE ANGLE OF ATTACK CHARTS, BUT IS NOT GUARANTEED. THE BORESIGHT TARGETS AND "μ" ANGLES ARE BASED ON THIS ANGLE OF ATTACK CHART.

μ = MIL ANGLE BETWEEN THE SIGHT LINE AND THE PROJECTILES AT ANY RANGE OUT TO 2000 FEET. WHEN THE MIL ANGLE IS MINUS THE PROJECTILES ARE ABOVE THE SIGHT LINE; WHEN PLUS THEY ARE BELOW. THIS MIL ANGLE ACTS ALONG THE VERTICAL AXIS OF THE SIGHT. THE MIL ANGLE "μ" IS ONLY APPLICABLE WHEN THE AIRCRAFT IS HARMONIZED AS SHOWN IN THE ABOVE BORESIGHT AND FIRE-IN TARGETS.

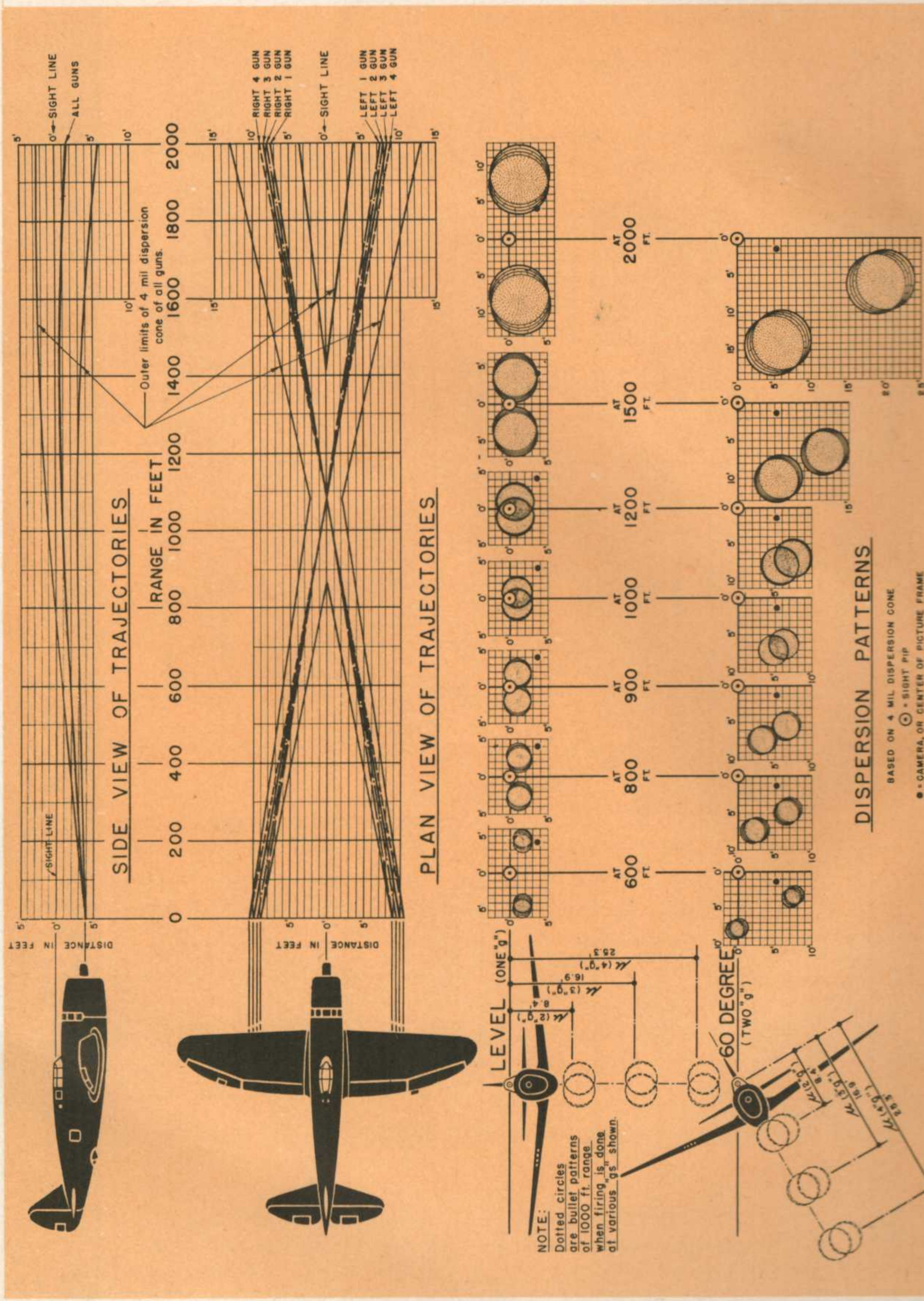
TRAJECTORY DATA - FORWARD FIRE

GUN	CAL. 0.50
AMMUNITION	A.P. M-2
MUZZLE VELOCITY- FT./SEC.	2700

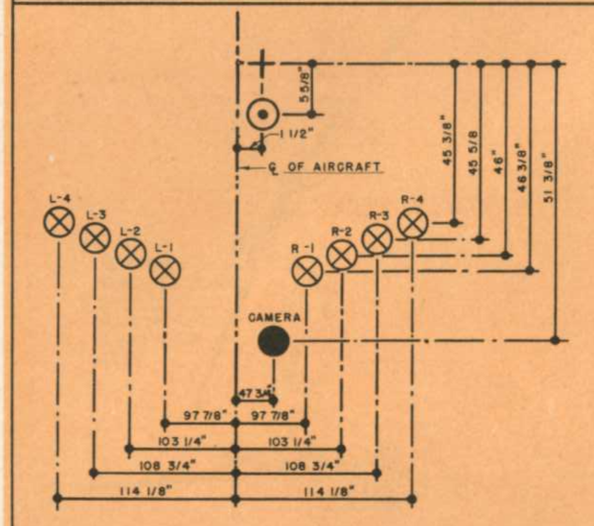
AUTHORITY ABERDEEN DATA FT. 50 AG-M-1, & 1ST IND. TO LETTER FROM ORD. DEPT. EGLIN FIELD, FLA. 15 APRIL, 1944 TO CHIEF OF ORDNANCE, WASHINGTON, D.C.

BASIC HARMONIZATION (300 M.P.H. CAL. I.A.S.)

AT 355 M.P.H. CAL. I.A.S., F.S.L. IS PARALLEL TO F.P.


SIDE VIEW OF TRAJECTORIES
SIGHT LINE
ALL GUNS
DISTANCE IN FEET
RANGE IN FEET
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Outer limits of 4 mil dispersion cone of all guns.
PLAN VIEW OF TRAJECTORIES
RIGHT 4 GUN
RIGHT 3 GUN
RIGHT 2 GUN
RIGHT 1 GUN
LEFT 1 GUN
LEFT 2 GUN
LEFT 3 GUN
LEFT 4 GUN
AT 600 FT.
AT 800 FT.
AT 900 FT.
AT 1000 FT.
AT 1200 FT.
AT 1500 FT.
AT 2000 FT.
DISPERSION PATTERNS
BASED ON 4 MIL DISPERSION CONE
⊙ = SIGHT PIP
● = CAMERA, OR CENTER OF PICTURE FRAME
LEVEL (ONE "g")
60 DEGREE (TWO "g")
8.4'
16.9'
25.3'
(2"g")
(3"g")
(4"g")
NOTE: Dotted circles are bullet patterns of 1000 ft. range when firing is done at various "g's" shown.

1000 INCH BORESIGHT TARGET



TARGETS SHOWN ARE FOR HARMONIZATION UNDER THE FOLLOWING CONDITIONS. (BASIC HARMONIZATION)

CAL. I.A.S. = 300 M.P.H.
ALTITUDE = 15,000 FT.
T.A.S. = ±373 M.P.H.
WEIGHT = 14,000 LBS. ± 250 LBS.
ANGLE OF ATTACK (α_p) = 11 MILS NOSE UP
LEVEL FLIGHT (1"g")

+ = MARK WHERE LINE FROM SIGHT IS PARALLEL TO FUSELAGE LEVELING LUGS.

⊙ = MARK WHERE SIGHT PIP IS AIMED FOR HARMONIZATION WITH BULLET PATTERNS - (SIGHT SETTING FOR THIS HARMONIZATION)

⊗ = MARK WHERE BORE IS AIMED FOR 1000 INCH AND 900 FOOT TARGETS.

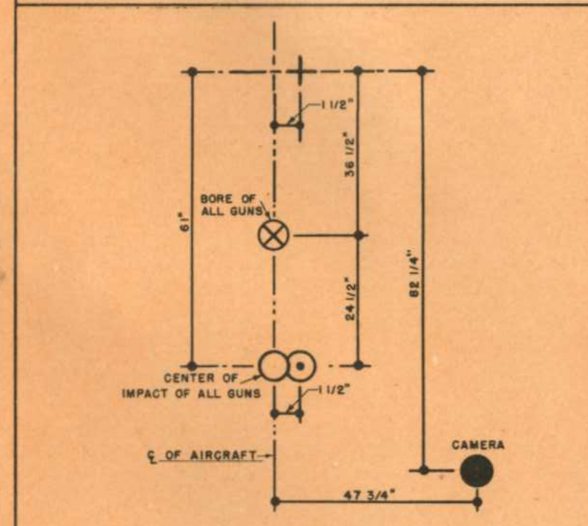
○ = MARK FOR CENTER OF IMPACT OF 10 ROUNDS AT 900 FT. TARGET.

● = MARK WHERE CAMERA IS AIMED, MAKING CAMERA PARALLEL TO SIGHT LINE. THIS POINT REPRESENTS THE CENTER OF PICTURE FRAME.

GUN LOCATION AT AIRCRAFT

CALIBER 0.50	VERT. (FROM SIGHT)	HORIZ. (FROM PLANE ℄)
L.&R. NO. 1 GUNS	47.344"	107.875"
L.&R. NO. 2 GUNS	46.969"	113.844"
L.&R. NO. 3 GUNS	46.594"	119.813"
L.&R. NO. 4 GUNS	46.219"	125.78"
CAMERA	45.750"	47.813"

900 FT. FIRE-IN & BORESIGHT TARGET



FLIGHT ANGLE	ALT.	Cal IAS	± TAS	MIL ANGLE "μ" 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	0'	250	250	+2.1	+10.7	+19.2	+27.8
		300	300	−0.3	+6.7	+13.7	+20.7
		350	350	−2.2	+3.8	+9.5	+15.4
		400	400	−4.0	+0.9	+6.2	+11.2
		450	450	−4.9	−0.6	+3.7	+8.0
	7000'	200	222	+6.1	+18.0	—	—
		250	276	+2.4	+11.8	+21.1	+30.5
		300	331	−0.2	+7.4	+15.1	+22.7
		350	386	−2.2	+4.2	+10.5	+16.9
		400	440	−4.0	+1.1	+6.9	+12.3
	15000'	200	251	+7.0	+20.3	—	—
		250	313	+2.9	+13.4	+23.7	+34.2
		300	373	0	+8.4	+16.9	+25.3
		350	434	−2.2	+4.9	+11.7	+18.8
		400	493	−4.0	+1.4	+7.7	+13.6
	30000'	150	242	+16.8	—	—	—
		200	320	+9.1	+25.5	—	—
		250	398	+4.0	+16.8	+29.5	+42.3
		300	471	+0.4	+10.6	+20.8	+31.0
		350	543	−2.2	+6.2	+14.4	+22.8

FLIGHT ANGLE	Cal IAS	αp (WT. = 14000 LBS.) 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	150	+161	–	–	–
	200	+74	+185	–	–
	250	+33	+105	+176	+248
	300	+11	+61	+111	+161
	350	−2	+35	+71	+108
	400	−11	+15	+45	+73
	450	−16	+6	+28	+50

αp = MIL ANGLE BETWEEN THE FUSELAGE LEVELING LUGS AND THE FLIGHT PATH. THIS DATA IS DERIVED FROM THE BEST AVAILABLE ANGLE OF ATTACK CHARTS, BUT IS NOT GUARANTEED. THE BORE-SIGHT TARGETS AND "μ" ANGLES ARE BASED ON THIS ANGLE OF ATTACK CHART.

μ = MIL ANGLE BETWEEN THE SIGHT LINE AND THE PROJECTILES AT ANY RANGE OUT TO 2000 FEET. WHEN THE MIL ANGLE IS MINUS THE PROJECTILES ARE ABOVE THE SIGHT LINE; WHEN PLUS THEY ARE BELOW. THIS MIL ANGLE ACTS ALONG THE VERTICAL AXIS OF THE SIGHT. THE MIL ANGLE "μ" IS ONLY APPLICABLE WHEN THE AIRCRAFT IS HARMONIZED AS SHOWN IN THE ABOVE BORESIGHT AND FIRE-IN TARGETS.

TRAJECTORY DATA - FORWARD FIRE

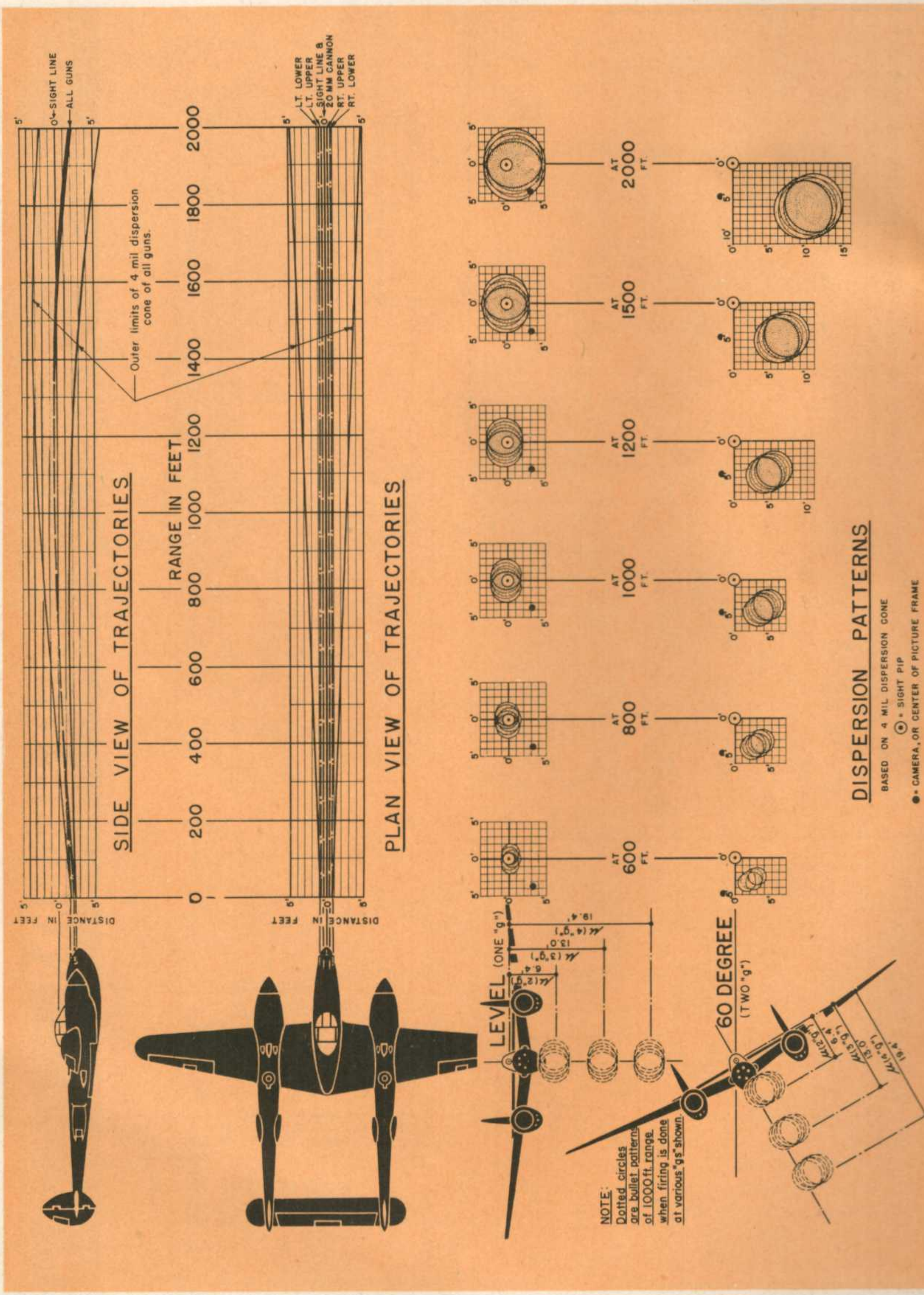
GUN	CAL. 0.50
AMMUNITION	A.P.M-2
MUZZLE VELOCITY-FT/SEC.	2700

AUTHORITY ABERDEEN DATA FT 50 AC-M-1, & 1ST IND. TO LETTER FROM ORD. DEPT. EGLIN FIELD, FLA. 15 APRIL 1944 TO CHIEF OF ORDNANCE, WASHINGTON, D.C.

HARMONIZATION CHART P-47D

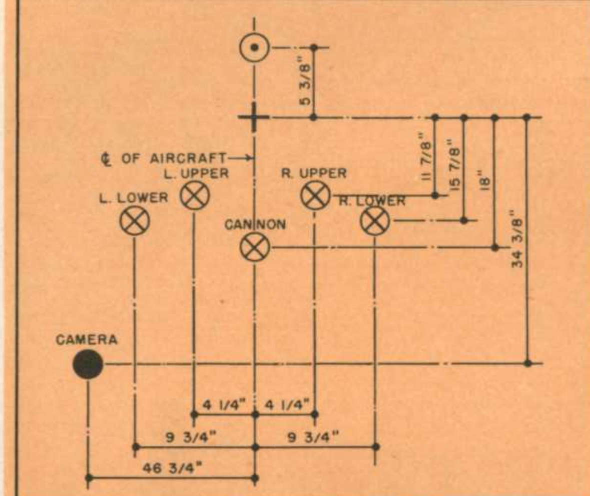
BASIC HARMONIZATION (300 M.P.H. CAL. I.A.S.)

AT 318 M.P.H. CAL. I.A.S., F.S.L. IS PARALLEL TO F.P.


SIDE VIEW OF TRAJECTORIES
RANGE IN FEET
0
200
400
600
800
1000
1200
1400
1600
1800
2000
SIGHT LINE
ALL GUNS
Outer limits of 4 mil dispersion cone of all guns.
DISTANCE IN FEET
PLAN VIEW OF TRAJECTORIES
LT. LOWER
LT. UPPER
SIGHT LINE & 20 MM CANNON
RT. UPPER
RT. LOWER
AT 600 FT.
AT 800 FT.
AT 1000 FT.
AT 1200 FT.
AT 1500 FT.
AT 2000 FT.
DISPERSION PATTERNS
BASED ON 4 MIL DISPERSION CONE
= SIGHT PIP
= CAMERA, OR CENTER OF PICTURE FRAME
LEVEL (ONE "g")
6.4
13.0
19.4
60 DEGREE (TWO "g")
NOTE: Dotted circles are bullet patterns of 1000ft. range when firing is done at various "g's" shown.

HARMONIZATION CHART P-38L

1000 INCH BORESIGHT TARGET



TARGETS SHOWN ARE FOR HARMONIZATION UNDER THE FOLLOWING CONDITIONS: (BASIC HARMONIZATION)

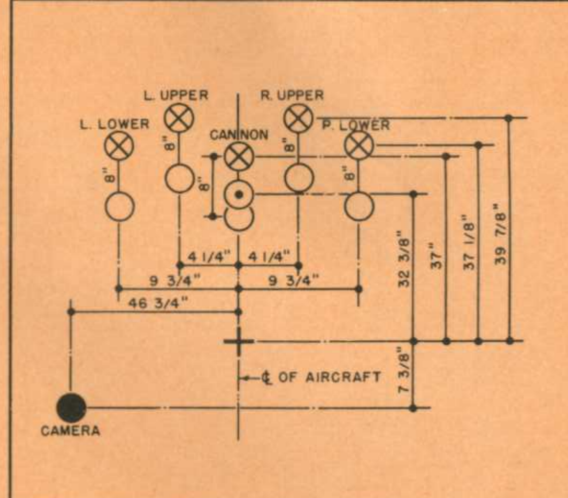
CAL. I.A.S. = 300 M.P.H.
ALTITUDE = 15,000 FT.
T.A.S. = ± 373 M.P.H.
WEIGHT = 14,700 LBS. ± 250 LBS.
ANGLE OF ATTACK (∝p) = 4 MILS NOSE DOWN
LEVEL FLIGHT (1"g")

- + = MARK WHERE LINE FROM SIGHT IS PARALLEL TO FUSELAGE LEVELING LUGS.
- ⊙ = MARK WHERE SIGHT PIP IS AIMED FOR HARMONIZATION WITH BULLET PATTERNS - (SIGHT SETTING FOR THIS HARMONIZATION)
- ⊗ = MARK WHERE BORE IS AIMED FOR 1000 INCH AND 500 FOOT TARGETS.
- ○ = MARK FOR CENTER OF IMPACT OF 10 ROUNDS AT 500 FT. TARGET.
- ● = MARK WHERE CAMERA IS AIMED MAKING CAMERA PARALLEL TO SIGHT LINE. THIS POINT REPRESENTS THE CENTER OF THE PICTURE FRAME.

GUN LOCATION AT AIRCRAFT

	VERT. (FROM SIGHT)	HORIZ. (FROM PLANE ¢)
.50 CAL. L. & R. UPPER GUNS	21.94"	4.25"
.50 CAL. L. & R. LOWER GUNS	26.44"	9.75"
20 MM CANNON	28.95"	0
CAMERA	39.82"	46.69"

500 FT. FIRE-IN & BORESIGHT TARGET



FLIGHT ANGLE	ALT.	Cal IAS	± TAS	MIL ANGLE "μ" 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	0'	250	250	+1.7	+8.3	+15.0	+21.6
		300	300	−0.2	+5.1	+10.6	+15.9
		350	350	−1.5	+2.8	+7.3	+11.5
		400	400	−2.8	+1.0	+4.9	+8.6
		450	450	−3.9	−0.6	+2.7	+6.1
	7000'	200	222	+4.8	+14.1	+23.3	—
		250	276	+2.0	+9.1	+16.4	+23.6
		300	331	−0.1	+5.7	+11.6	+17.4
		350	386	−1.5	+3.2	+8.0	+12.5
		400	440	−2.9	+1.1	+5.4	+9.4
	15000'	200	251	+5.5	+15.8	+26.1	—
		250	313	+2.3	+10.3	+18.5	+26.5
		300	373	0	+6.4	+13.0	+19.4
		350	434	−1.6	+3.6	+8.9	+13.9
		400	493	−3.1	+1.4	+6.0	+10.4
	30000'	150	242	+13.0	—	—	—
		200	320	+7.0	+19.7	+32.5	—
		250	398	+3.1	+12.9	+22.8	+32.6
		300	471	+0.2	+8.0	+15.9	+23.8
		350	543	−1.6	+4.5	+10.9	+16.8

FLIGHT ANGLE	Cal IAS	∝p (WT. = 14700 LBS.) 1 "g"	2 "g"	3 "g"	4 "g"
LEVEL FLIGHT	150	+111	—	—	—
	200	+44	+130	+216	—
	250	+13	+68	+124	+179
	300	−4	+34	+73	+111
	350	−13	+14	+42	+68
	400	−20	+1	+23	+44
	450	−25	−8	+9	+26

∝p = MIL ANGLE BETWEEN THE FUSELAGE LEVELING LUGS AND THE FLIGHT PATH. THIS DATA IS DERIVED FROM THE BEST AVAILABLE ANGLE OF ATTACK CHARTS, BUT IS NOT GUARANTEED. THE BORESIGHT TARGETS AND "μ" ANGLES ARE BASED ON THIS ANGLE OF ATTACK CHART.

μ = MIL ANGLE BETWEEN THE SIGHT LINE AND THE PROJECTILES AT ANY RANGE OUT TO 2000 FEET. WHEN THE MIL ANGLE IS MINUS THE PROJECTILES ARE ABOVE THE SIGHT LINE; WHEN PLUS THEY ARE BELOW. THIS MIL ANGLE ACTS ALONG THE VERTICAL AXIS OF THE SIGHT. THE MIL ANGLE "μ" IS ONLY APPLICABLE WHEN THE AIRCRAFT IS HARMONIZED AS SHOWN IN THE ABOVE BORESIGHT AND FIRE-IN TARGETS.

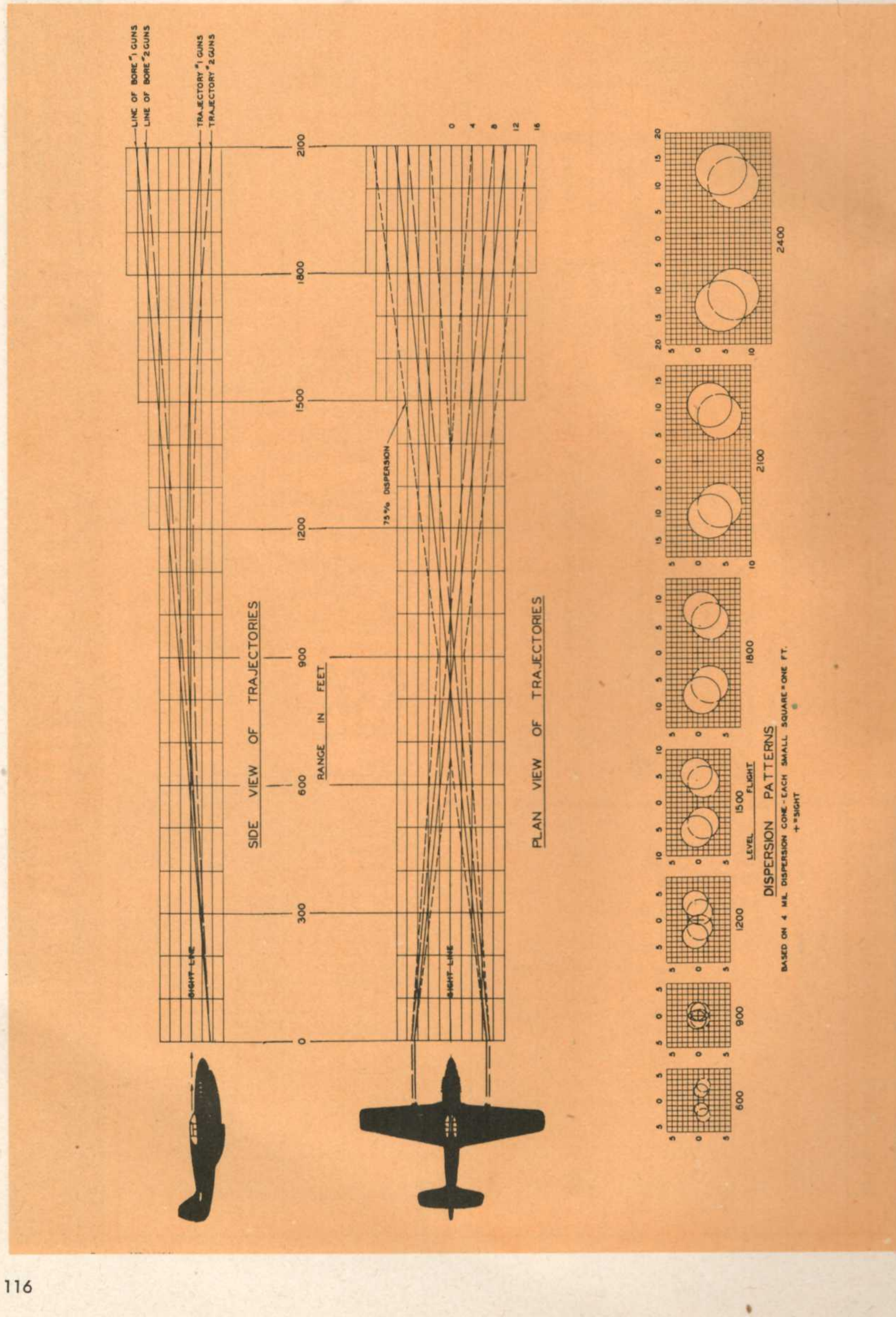
TRAJECTORY DATA - FORWARD FIRE

GUN	20 MM	CAL. 0.50
AMMUNITION	H.E. T-23, P.D. FUZE T71E4	A.P. M-2
MUZ. VEL. F/S	2750	2700

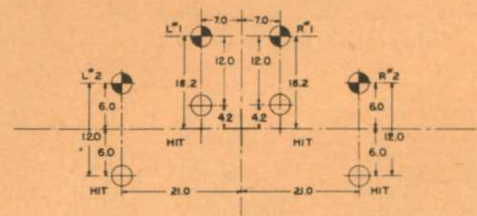
AUTHORITY: ABERDEEN DATA FT. 20 AC-I-1; FT. 50AC-M-1, & 1ST IND. TO LETTER FROM ORD. DEPT. EGLIN FIELD, FLA. 15 APRIL 1944 TO CHIEF OF ORDNANCE, WASHINGTON, D.C.

BASIC HARMONIZATION (300 M.P.H. CAL. I.A.S.)

AT 307 M.P.H. CAL. I.A.S. F.S.L. IS PARALLEL TO F.P.



SIDE VIEW OF TRAJECTORIES
LINE OF BORE #1 GUNS
LINE OF BORE #2 GUNS
TRAJECTORY #1 GUNS
TRAJECTORY #2 GUNS
SIGHT LINE
0
300
600
900
1200
1500
1800
2100
RANGE IN FEET
PLAN VIEW OF TRAJECTORIES
75% DISPERSION
SIGHT LINE
0
4
8
12
16
DISPERSION PATTERNS
BASED ON 4 MIL DISPERSION CONE - EACH SMALL SQUARE = ONE FT.
+ = SIGHT
LEVEL FLIGHT
600
900
1200
1500
1800
2100
2400



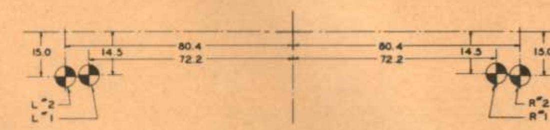
750 FT. FIRE-IN & BORESIGHT TARGET

ALL DIMENSIONS GIVEN IN INCHES
THE ABOVE SCALE NOT A TRUE PORPORTION

+ = sight mark, when sight is set to angle of attack.

◐ = mark where bore should be aimed.

○ = mark where center of dispersion should be at 750 ft. 10 rounds should be fired from each gun and pattern should center on these points.



1000 INCH BORESIGHT TARGET

GUN	LOCATION AIRCRAFT	AT
CALIBER 0.50	VERTICAL FROM SIGHT	HORIZONTAL FROM ℄ PLANE
L & R NO. 1	40.238	80.508
L & R NO. 2	40.124	87.998
CAMERA	48.543	36.0

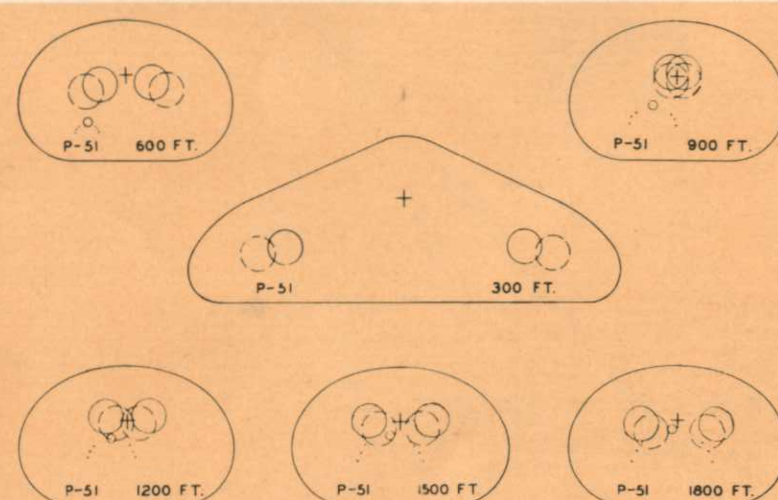
GSAP EXACT ASSESSOR

BULLET GROUP TEMPLATES

Circles indicate dispersion area wherein 75% of all bullets fired will go.

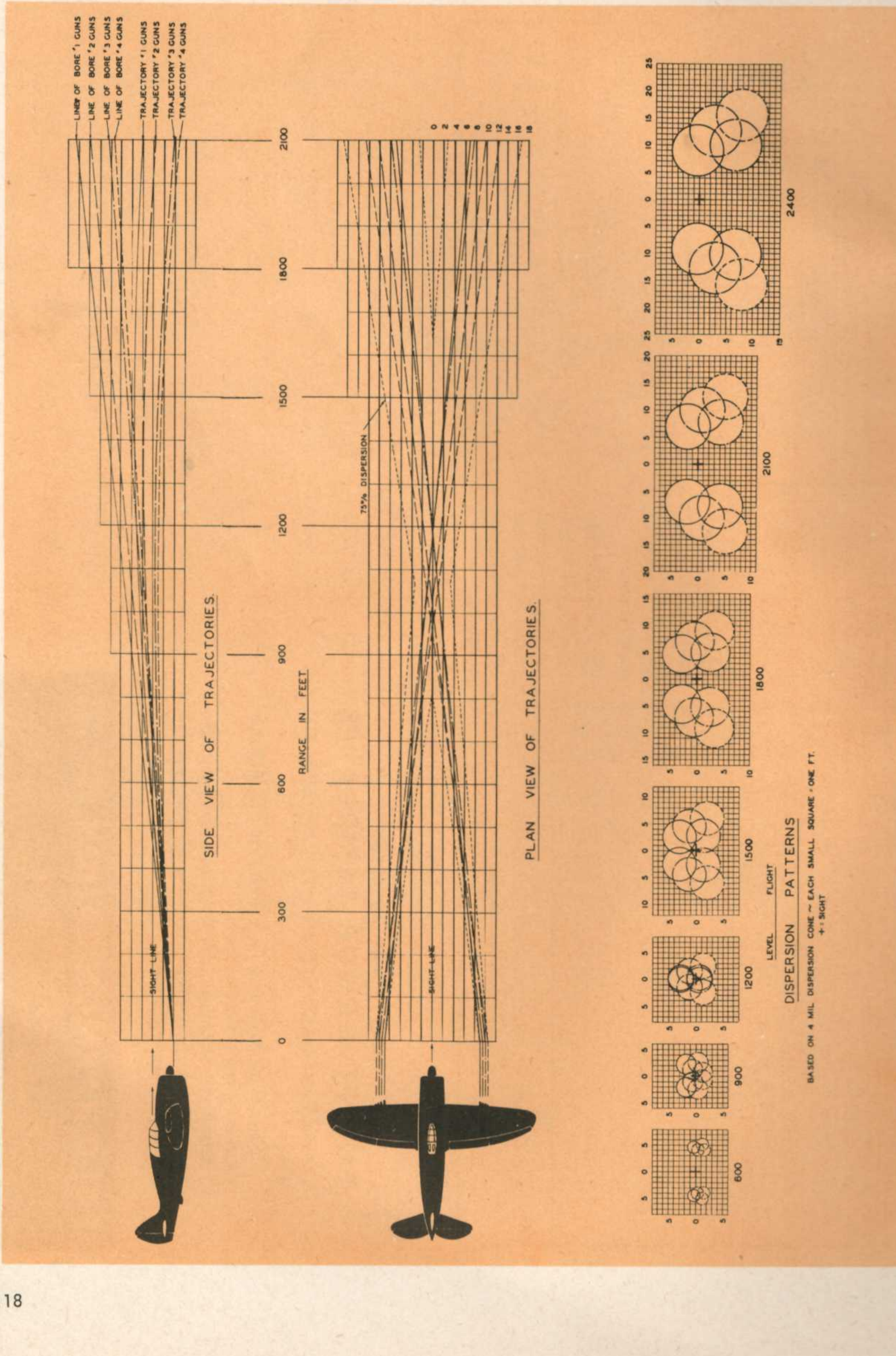
Templates are to scale; to use, enlarge them until dispersion circles equal four mils on the screen.

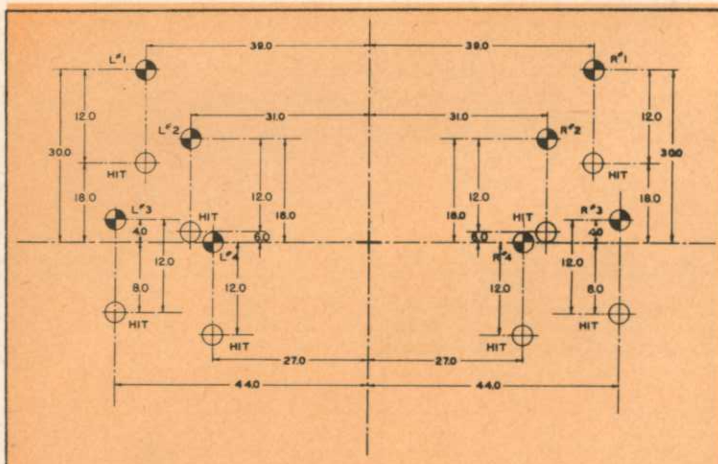
Small circles are assessor attachment points for level flight. Additional dots are attachment points for 45°, 60° and 75°, right and left bank respectively.



P 51-D HARMONIZATION CHART AND PATTERNS

No. 51 H-4
AAFIS FIXED GUNNERY
MATAGORDA PENINSULA, TEXAS


LINE OF BORE #1 GUNS
LINE OF BORE #2 GUNS
LINE OF BORE #3 GUNS
LINE OF BORE #4 GUNS
TRAJECTORY #1 GUNS
TRAJECTORY #2 GUNS
TRAJECTORY #3 GUNS
TRAJECTORY #4 GUNS
SIDE VIEW OF TRAJECTORIES
SIGHT LINE
0
300
600
900
1200
1500
1800
2100
RANGE IN FEET
PLAN VIEW OF TRAJECTORIES
75% DISPERSION
SIGHT LINE
DISPERSION PATTERNS
LEVEL FLIGHT
600
900
1200
1500
1800
2100
2400
BASED ON 4 MIL DISPERSION CONE ~ EACH SMALL SQUARE = ONE FT.
+ = SIGHT



750 FT. FIRE-IN & BORESIGHT TARGET.

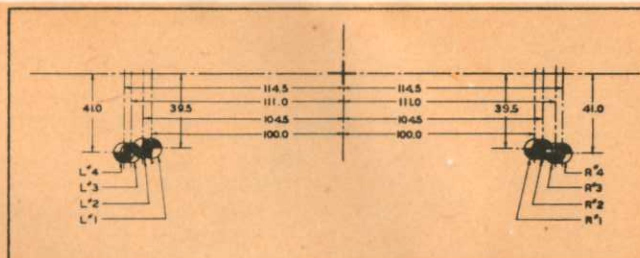
ALL DIMENSIONS GIVEN IN INCHES

THE ABOVE SCALE NOT A TRUE PORPORTION

+ = sight mark, when sight is set to angle of attack.

◐ = mark where bore should be aimed.

○ = mark where center of dispersion should be at 750 ft. 10 rounds should be fired from each gun and pattern should center on these points.



1000 INCH BORESIGHT TARGET.

GUN	LOCATION AIRCRAFT	AT
CALIBER 0.50	VERTICAL FROM SIGHT	HORIZONTAL FROM ℄ PLANE
L & R NO. 1	47.34	107.88
L & R NO. 2	46.97	113.84
L & R NO. 3	46.60	119.81
L & R NO. 4	46.22	125.78
CAMERA	47.81	45.75

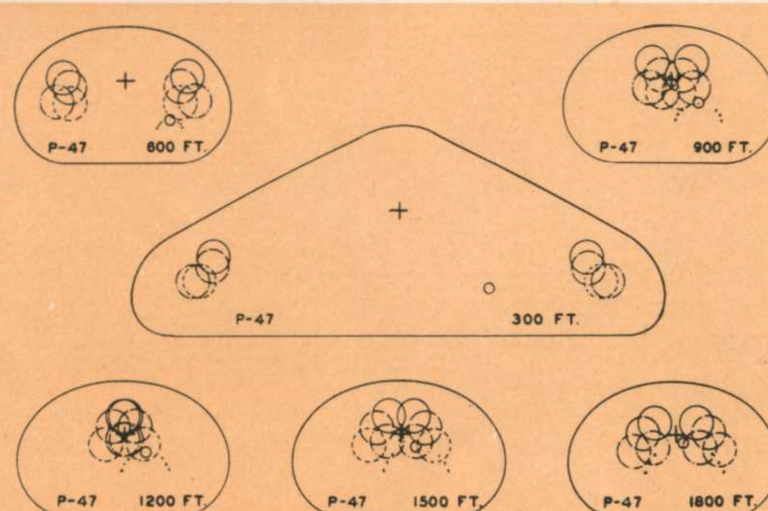
GSAP EXACT ASSESSOR

BULLET GROUP TEMPLATES

Circles indicate dispersion area wherein 75% of all bullets fired will go.

Templates are to scale; to use, enlarge them until dispersion circles equal four mils on the screen.

Small circles are assessor attachment points for level flight. Additional dots are attachment points for 45°, 60° and 75° right and left bank respectively.

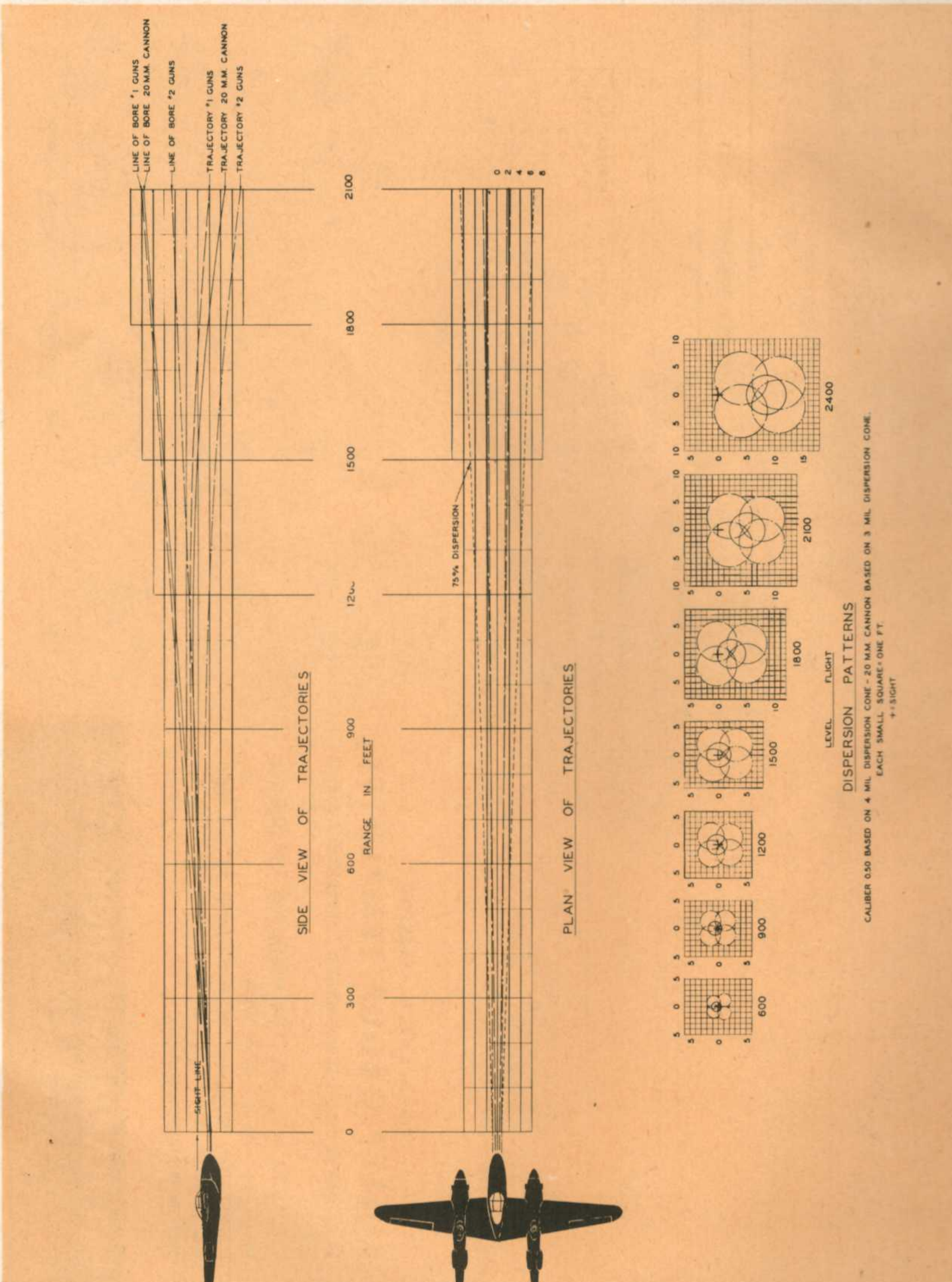


P 47-D HARMONIZATION CHART AND PATTERNS

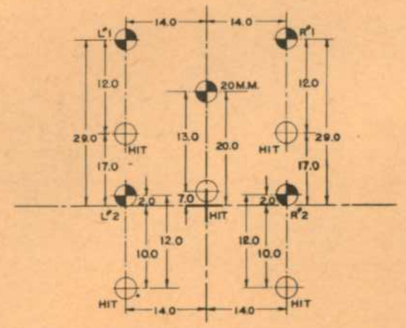
No. 47 H-8

AAFIS FIXED GUNNERY

MATAGORDA PENINSULA, TEXAS



LINE OF BORE #1 GUNS
LINE OF BORE 20 M.M. CANNON
LINE OF BORE #2 GUNS
TRAJECTORY #1 GUNS
TRAJECTORY 20 M.M. CANNON
TRAJECTORY #2 GUNS
SIGHT LINE
0
300
600
900
1200
1500
1800
2100
RANGE IN FEET
SIDE VIEW OF TRAJECTORIES
75% DISPERSION
PLAN VIEW OF TRAJECTORIES
600
900
1200
1500
1800
2100
2400
LEVEL FLIGHT
DISPERSION PATTERNS
CALIBER 0.50 BASED ON 4 MIL DISPERSION CONE - 20 M.M. CANNON BASED ON 3 MIL DISPERSION CONE.
EACH SMALL SQUARE = ONE FT.
+ = SIGHT



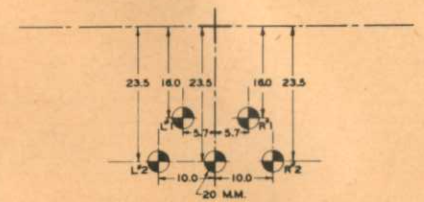
750 FT. FIRE-IN & BORESIGHT TARGET

ALL DIMENSIONS GIVEN IN INCHES
THE ABOVE SCALE NOT A TRUE PORPORTION

+ = sight mark, when sight is set to angle of attack.

◑ = mark where bore should be aimed.

○ = mark where center of dispersion should be at 750 ft. 10 rounds should be fired from each gun and pattern should center on these points.



1000 INCH BORESIGHT TARGET

GUN	LOCATION AIRCRAFT	AT
CALIBER 0.50	VERTICAL FROM SIGHT	HORIZONTAL FROM ℄ PLANE
L & R NO. 1	21.94	4.63
L & R NO. 2	26.44	9.84
20 M.M. CANNON	28.95	0
CAMERA	42.16	0

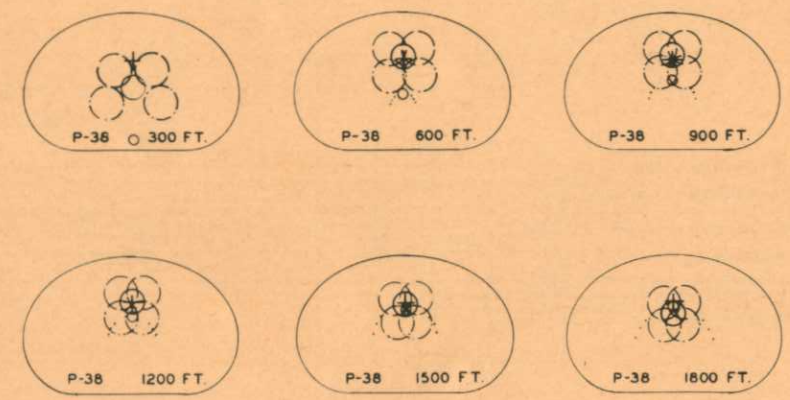
GSAP EXACT ASSESSOR

BULLET GROUP TEMPLATES

Circles indicate dispersion area wherein 75% of all bullets fired will go.

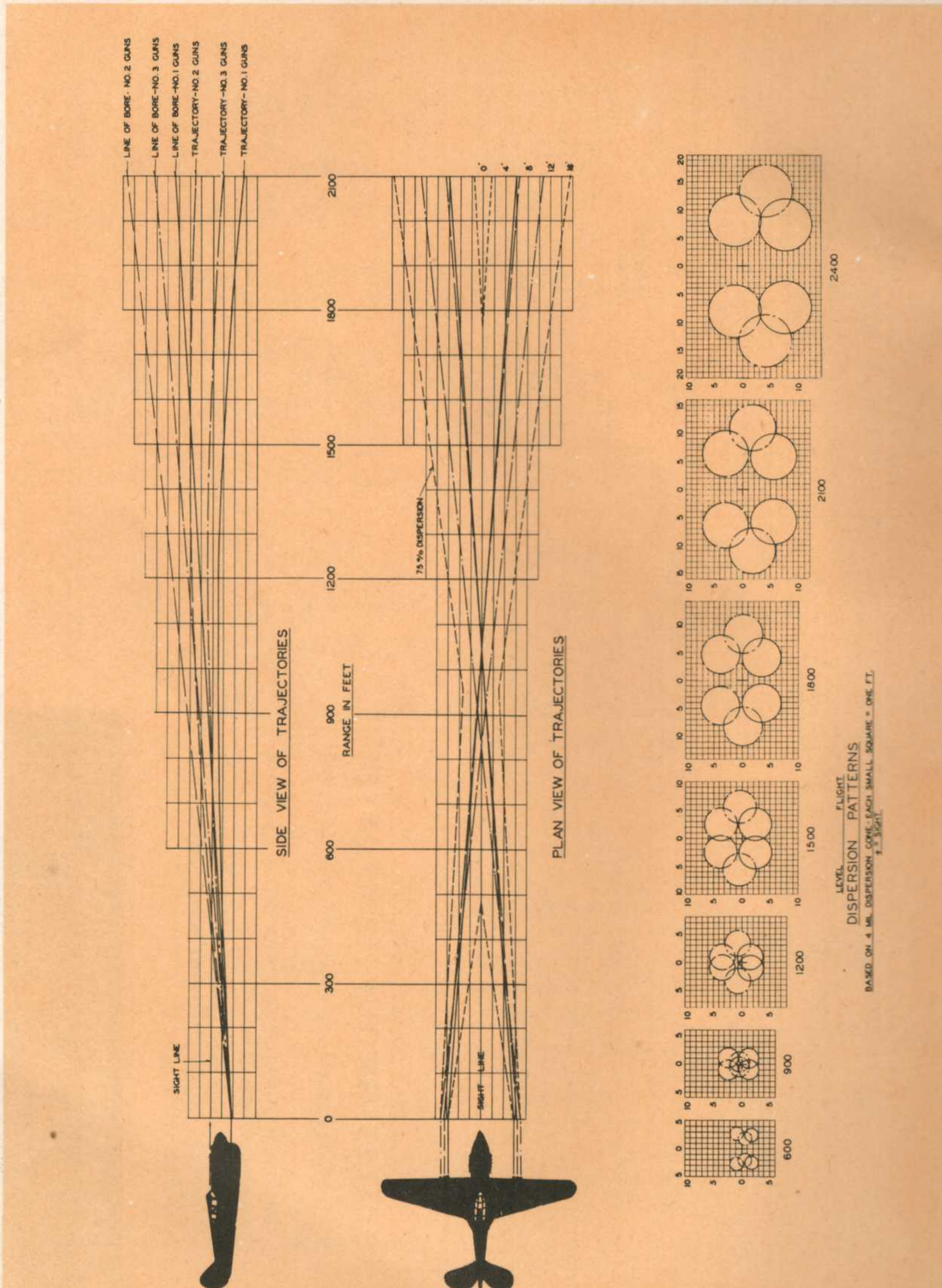
Templates are to scale; to use, enlarge them until dispersion circles equal four mils on the screen.

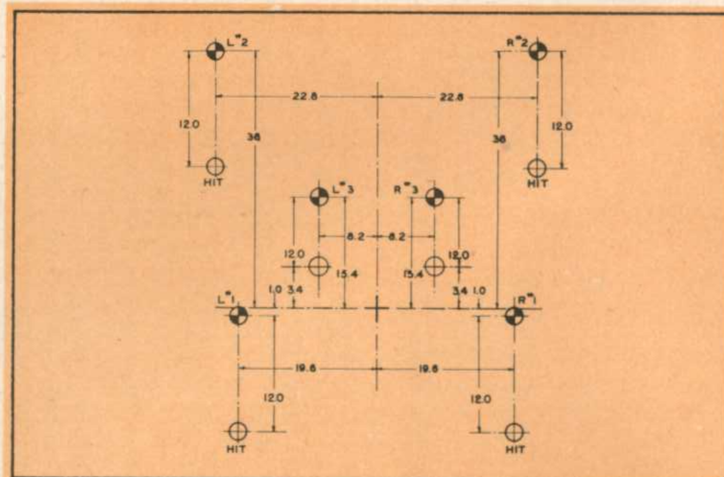
Small circles are assessor attachment points for level flight. Additional dots are attachment points for 45°, 60° and 75°, right and left bank respectively.



P 38-L HARMONIZATION CHART AND PATTERNS

No. 38 C-5
AAFIS FIXED GUNNERY
MATAGORDA PENINSULA, TEXAS


LINE OF BORE - NO. 2 GUNS
LINE OF BORE - NO. 3 GUNS
LINE OF BORE - NO. 1 GUNS
TRAJECTORY - NO. 2 GUNS
TRAJECTORY - NO. 3 GUNS
TRAJECTORY - NO. 1 GUNS
SIGHT LINE
SIDE VIEW OF TRAJECTORIES
0
300
600
900
1200
1500
1800
2100
RANGE IN FEET
75 % DISPERSION
PLAN VIEW OF TRAJECTORIES
600
900
1200
1500
1800
2100
2400
LEVEL FLIGHT
DISPERSION PATTERNS
BASED ON 4 MIL DISPERSION CONE - EACH SMALL SQUARE = ONE FT.



750 FT. FIRE-IN & BORESIGHT TARGET

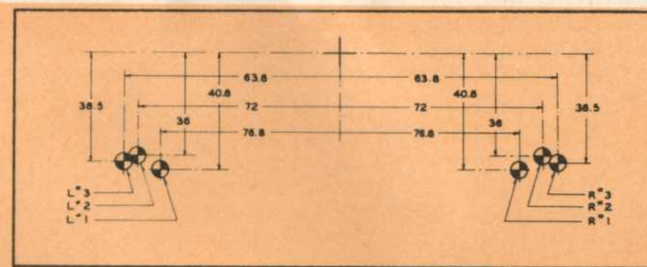
ALL DIMENSIONS GIVEN IN INCHES

THE ABOVE SCALE NOT A TRUE PORPORTION

+ = sight mark, when sight is set to angle of attack.

= mark where bore should be aimed.

○ = mark where center of dispersion should be at 750 ft. 10 rounds should be fired from each gun and pattern should center on these points.



1000 INCH BORESIGHT TARGET

GUN	LOCATION AIRCRAFT	AT
CALIBER 0.50	VERTICAL FROM SIGHT	HORIZONTAL FROM ℄ PLANE
L & R NO. 1	45.43"	69.68"
L & R NO. 2	44.39"	77.18"
L & R NO. 3	43.39"	85.16"
CAMERA	35.00	40.00

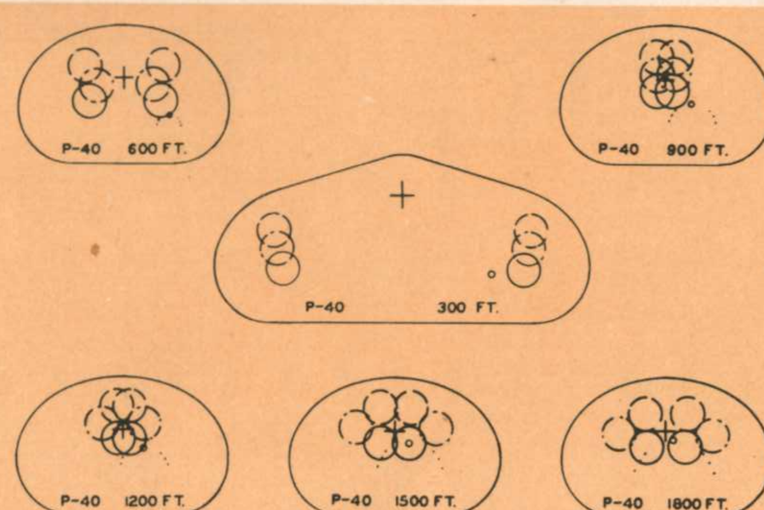
GSAP EXACT ASSESSOR

BULLET GROUP TEMPLATES

Circles indicate dispersion area wherein 75% of all bullets fired will go.

Templates are to scale; to use, enlarge them until dispersion circles equal four mils on the screen.

Small circles are assessor attachment points for level flight. Additional dots are attachment points for 45°, 60° and 75°, right and left bank respectively.

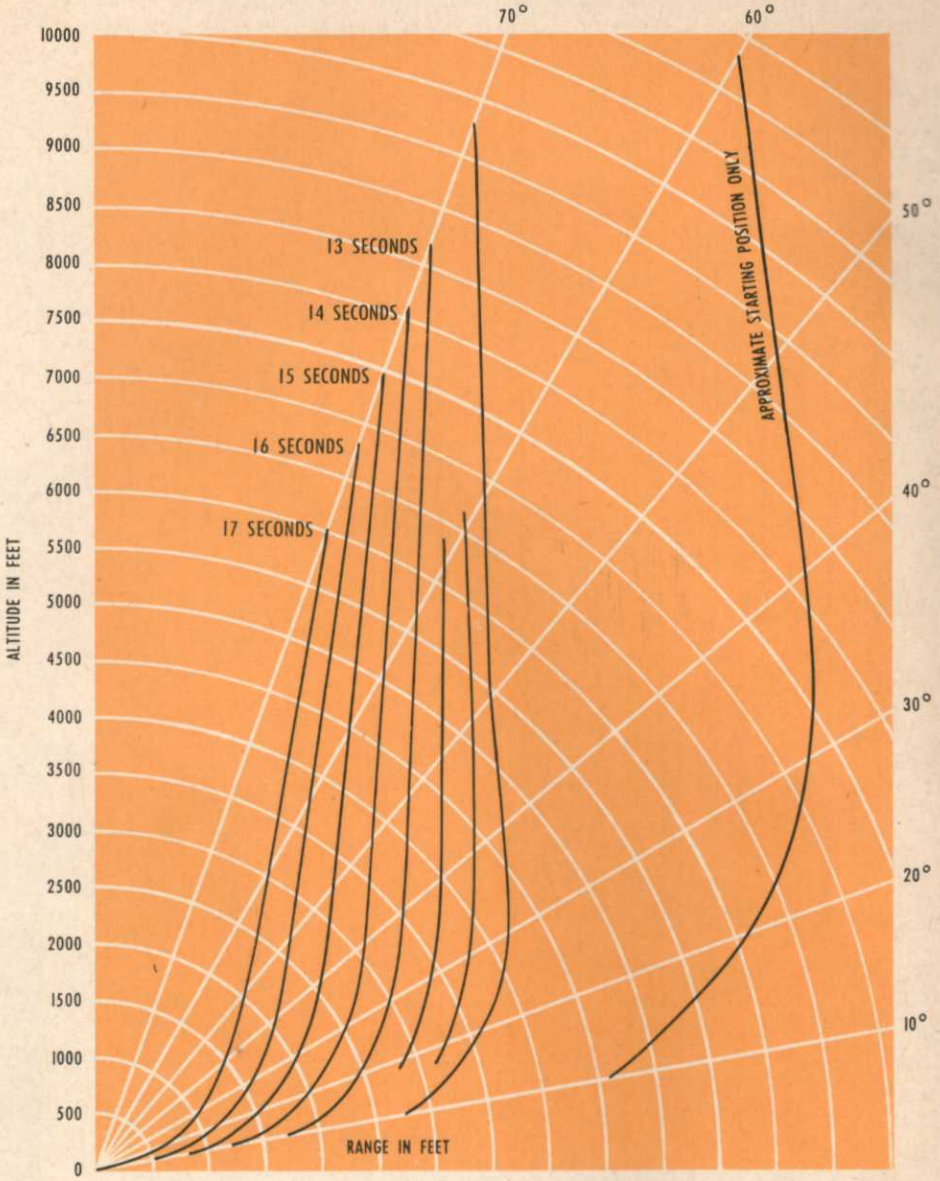


P 40-N HARMONIZATION CHART AND PATTERNS

No. 40 C-6

AAFIS FIXED GUNNERY

MATAGORDA PENINSULA, TEXAS



SLANT RANGE CHART FOR VARIOUS DIVE ANGLES AND TIME DELAYS

This chart is based on data derived from averages of test missions flown by various fighter aircraft and does not represent the performance of any one type. Airplane types used to derive these curves were P-51A, P-51D, P-47C, P-47D, P-40R, and P-38L. The chart gives an approximation of the airplane's position at any time during a dive which is accurate enough to be used on present gun camera film assessment for ground attack dives.

Use the chart in the following manner: A 40° dive is being made with a 14 second time delay. To find the desired range move down the 40° line until it crosses the curves marked 13 and 14 seconds respectively. Half way between the 13 and 14 seconds lines is the desired slant range for a 40° dive with a 14 second time delay. The chart shows that this slant range is approximately 3,250 feet; however, any range between 3,100 and 3,500 feet may be considered satisfactory for the conditions given. If the gun camera range assessment is not between these values there was either an error in the pilot's time count or in his initial entry position. You can evaluate any practice dive by the same procedure. The two shorter unmarked curves running from 20° to 60° represent the 12 and 11 second delay curves.

New Era Litho. N. Y. 20M—4-45